Vol. X, Part IV August, 1940

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

Issued under the authority

of

The Imperial Council of Agricultural Research

Annual subscription
Rs. 15 or 23s. 6d.

Price per part
Rs. 3 or 5s.

PUBLISHED BY THE MANAGER OF PUBLICATIONS, DELHI
PRINTED BY THE MANAGER, GOVERNMENT OF INDIA PRESS, NEW DELHI
1940

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ORIGINAL ARTICLES

THE EFFECT OF DIFFERENTIAL IRRIGATION AND SPACING ON THE FIELD BEHAVIOUR AND QUALITY OF CAMBODIA CO 2 COTTON

BY

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(Received for publication on 22 February 1938)

(With two text-figures)

Introduction

MORE than five lakhs of acres are being cropped under Cambodia cotton (*G. hirsutum*) in Madras province. Nearly 60 per cent of this area is being irrigated from water lifted from wells with a low water-table. Irrigation in such places forms an expensive item in the cost of production. Surprisingly enough, the cotton growers there go on irrigating their crop very frequently without considering the requirements of the plants. Such a practice, not only reduces their margin of profit, but also precludes them from making the best use of the limited supply of water available in the wells.

It was thought desirable to determine the optimum frequency of irrigation for a crop of Cambodia cotton and to study whether such frequencies would affect the qualities of fibres.

Material and methods

For this purpose experiments were conducted during 1932-35 on the cotton breeding station situated in Coimbatore district, which contains the highest acreage in the province under Cambodia cotton. Their particulars are described, for the sake of easy reference, under the following heads :—

(*a*) *Nature of the soil.*—In the trials conducted during the first two years, the soils were reddish loam but they were of different depths. In the first year, the kankar layer was below five feet, while in the second, it was within two feet at some places. The soil used in the third year was distinctly alkaline and heavy, with defective drainage. These soils could, however, be taken as fairly representative of the types of soil over which Cambodia cotton is being grown in that district.

(*b*) *Time of sowing.*—Generally this exotic cotton is usually sown in October-November soon after the onset of the north-east monsoon. It has, however, been found in the experiments carried out by the department a few years ago, that the yields increased by more than 30 per cent when sown in early September and this time of sowing was adopted for the experiments reported here.

(c) *Method of sowing.*—The cotton growers are in the habit of sowing the seeds broadcast and then forming channels and beds for irrigation. The Agricultural department found after certain trials that sowing in lines 2½ to 3 feet apart facilitated intercultivation and picking operations, and began to advocate that method as superior. Since line sowing would mean the division of the land into ridges, and since formation of ridges and furrows would affect the quantity of water consumed by the crop, both the methods, viz. the farmer's practice of sowing and irrigating in beds, and the departmental advice of throwing the land into ridges and furrows three feet apart, were used for comparison. In the ridged series, however, two separate spacings of 4 in. and 9 in. between two consecutive holes were included. The average stand of plants in these spacings are given in the following statement.

Average number of plants in 1/100 acre plots

1932-33			1933-34			1934-35		
4 in.	9 in.	Beds	4 in.	9 in.	Beds	4 in.	9 in.	Beds
324	150	208	338	137	219	272	128	217

It might be mentioned that in the bed series, a neighbouring cotton grower was asked to sow and thin in the way he usually did, so that it might be thoroughly representative of the farmer's conditions.

(d) *Size of plots.*—The plots were of two sizes. For the measurement of water used in each irrigation, the area of the full plot was taken into account while for the comparison of yields, smaller area in each plot was marked out in the centre with the object of removing the effects of the borders. In the ridged plots, the plots used for irrigation were seven ridges wide with no outskirts. But for the collection of data of yields, the central three ridges alone were taken, leaving two ridges as outskirts on each side. In addition a length of 6 ft. was cut out at both extremities of the ridges with a view to eliminate the effects of extra spacing and watering. In the flat bed series, areas equal to those obtained in the ridged plots were marked out in each treatment for the study of yields.

The ultimate area secured for yields was 1·3 cents in the first year and 1 cent in the next two years as against 3·7 cents and 2·8 cents used for irrigational treatments in those years.

In all the three years plots with no irrigation were included in the tests for reasons given on the next page. In the first year, these plots were of the same size as others, but it was noticed that the width of two ridges left out at each side of the central experimental area was not enough to cut away the effects of lateral seepage from the irrigated plots. The plots were therefore made wider in the subsequent two years. There were nine ridges in such treatments, out of which three ridges on each side of the central three rows were rejected for the determination of yields.

(*e*) *Irrigation frequencies.*—When cotton is sown in October-November with the starting of the north-east monsoon, the young plants grow in an over-saturated soil till the middle of December, by which time the rainy period ordinarily terminates. Thence onwards, dry weather prevails till the middle of April. It is during this period that the crops suffer from insufficiency of soil moisture. If the deficiency is not made up by artificial irrigation, the plants shed their buds and even bolls, with the result that the yield per acre is reduced from 900—1,000 lb. of *kapas* obtained under irrigated conditions to 400—500 lb. normally recorded on unirrigated fields. The irrigational treatments were therefore confined to the above periods of drought. All the plots were treated alike from the time of sowing up to that period. The crops were just producing stray flowers at the time of the first irrigation.

The farmers of Coimbatore generally irrigate their Cambodia cotton once in 12—15 days. It was thought sufficient to compare irrigation frequencies one shorter and another longer than this interval. The three variants chosen were, watering (1) once a week, (2) once in two weeks and (3) once in three weeks. These were compared with a set of plots that were not irrigated after the rains. Such plots were designated as 'dry'. Fortunately no heavy rains were received during the experimental period and those that fell were in the form of drizzles and not of such a magnitude as to seriously affect the treatments.

It might be mentioned here that the changes in irrigation frequencies were preferred to the quantities of water used in each watering, because of the fact that a recommendation made with regard to intervals between two consecutive irrigations would be more easily understood and put into normal practice by the farmers than one involving differences in the amount of water used in each irrigation, especially when no easy contrivance to measure water was available with them.

(*f*) *Measurement of water.*—Inasmuch as irrigations were to be carried out by both furrow and bed systems at different intervals, and since the amount of water consumed each time would be affected by the intervals between two consecutive irrigations, it was deemed necessary to measure the quantities of water used in each irrigation in all the treatments. This was made possible by the installation of a Kents Lea recorder. In this arrangement, the water pumped out from the well was first allowed into a masonry cistern to which was connected, by means of a small tube at the bottom, a smaller cistern which contained the float of Lea recorder. This float moved up and down with the level of water in the delivery cistern. This movement was automatically recorded by a needle on a chart wound round a drum moving slowly by means of clock work. On the chart were marked, in thousands of gallons, the quantities of water flowing out of a right-angled $\vee$ notch fixed at one end of the cistern. The water was then conveyed to the fields through cement channels with no loss of water by seepage along its course.

Arrangements were made to record the time taken for irrigating each treatment. The method adopted was to note with the aid of a stop-watch the difference between the time of entry of water into the first furrow or bed and that when the water was diverted from the last furrow or bed. The quantity of water consumed was calculated by multiplying the time taken for

irrigation by the rate of discharge as recorded during that period in the chart of the Lea recorder. To ensure that the watering done to each plot was of almost uniform depth at each irrigation, the following procedure was observed. In the furrow system the inlets were closed as soon as water reached the further ends, while in the bed system they were closed immediately the water was found to spread over the entire surface of the bed. It might be stated that this system was commonly practised by all the farmers and as such it needed no special effort to adopt.

(*g*) *Layout of treatments.*—The following 12 treatments made up of combinations of four irrigations and three spacings were compared.

Irrigations	Spacings
(*a*) No irrigation	4 in.
(*b*) Irrigation once a week	9 in.
(*c*) Irrigation once in 2 weeks	Broadcast
(*d*) Irrigation once in 3 weeks	in beds

Of these the two treatments—no irrigations with 4 in. spacings and no irrigation in broadcasted beds—were not included by mistake in the first year. The treatments were laid out in randomized blocks replicated four times during the first two years and three times in the third year.

During the course of the experiments some plants died as a result of the stem weevil (*Pempheres affinis*) attack in all the plots. It was therefore apprehended that the inequalities in stand thus brought about would have appreciably disturbed the final yields. The yield data were therefore adjusted to equal stand by means of covariance, but on comparing the standard error of the crude and adjusted yields (*vide* below) it was felt that no advantage would be gained by the use of adjusted yields. The crude yields themselves were used for the statistical analysis.

	Standard error of yields	
	Crude	Adjusted
	Per cent	Per cent
1932-33	9·6	12·0
1933-34	9·5	9·6
1934-35	13·3	12·6

(*h*) *Fibre-tests.*—These tests included the determination of the mean fibre-length, mean fibre-weight per inch and percentages of mature, half-mature and immature hairs and were carried out on samples of three seasons. The mean fibre-length was found by making one Balls Sorter and two Baer

Sorter tests. The mean fibre-weight per inch was found by weighing bunches of whole fibres on a sensitive quartz micro-balance. About 2,000 fibres in 14 to 20 bunches were weighed for each sample. The detailed technique of these tests is described in Bulletin Series A, No. 25, entitled ' Testing of Indian cottons for quality at the Technological Laboratory ', while the method for determining the maturity count of a cotton followed in these tests will be found in the Technological Bulletin, Series B, No. 20 entitled ' Fibre-maturity in relation to fibre and yarn characteristics of Indian cottons.'

(*i*) *Spinning technique and yarn tests.*—A full account of the spinning technique adopted in the laboratory, and details of machinery, settings, speeds, etc., are given in the Technological Bulletin, Series A, No. 25. Such specific details as the drafts, spindle speeds, front roller speeds, etc. for each sample will be found in the tables of spinning test results in the appendix . Each of the three counts of each sample was spun on ten bobbins and the following tests were made on each bobbin.

Description of tests	No. of tests
Lea strength and actual counts	5
Single thread strength and single thread extension	10
Turns per inch	10

The methods followed for carrying out these tests are given in the bulletin referred to above. Each test result given in the tables of spinning test results in the appendix represents the mean of 50 tests in the case of lea-strength and count, and 100 in the case of single thread strength, single thread extension and turns per inch. The tables of spinning tests results also contain the average values of temperature and relative humidity prevailing in the rooms during the spinning and testing of each yarn.

Evenness of a yarn was estimated by visual examination and expressed by means of a numeral in the spinning test tables. The number of neps present in a yarn was also counted at the same time as the yarn was examined for evenness. The count was made on 40 portions of yarn, each 3·6 inches long, ten portions being taken from a bobbin. Neppiness is expressed as the average number of neps per yard of yarn.

Results

The agronomic data are presented under two heads—water consumption and yields—while those concerning the fibre characters are furnished under three heads—graders' reports, fibre test results, and spinning test results.

(*a*) *Water consumption.*—These are dealt with under two sub-heads (1) total quantity of water consumed (Table I), (2) water used at each irrigations (Table II).

It will be seen from the table of analysis of variance given in Table IB that the block variances were significantly high in all the three years , and that notwithstanding them, those due to treatments were still greater in magnitude, signifying that the treatments showed distinctly different requirements of water. When they were scrutinized further, it was brought out that

TABLE I A

Average total quantity of water consumed by each treatment in acre-inches

Frequency of irrigation	1932-33				1933-34				1934-35			
	Ridge		Bed	Average	Ridge		Bed	Average	Ridge		Bed	Average
	4 in.	9 in.	Broad-cast		4 in.	9 in.	Broad-cast		4 in.	9 in.	Broad-cast	
1 week	14·6	14·7	16·1	15·1	18·6	19·5	19·5	19·2	16·9	16·8	15·2	16·3
2 week	9·2	8·7	10·3	9·4	11·1	10·3	10·9	10·7	9·0	9·5	9·2	9·3
3 week	6·3	6·2	7·5	6·7	7·1	7·2	7·4	7·2	5·9	5·7	5·6	5·7
Average	10·0	9·9	11·3	10·4	12·2	12·3	12·6	12·4	10·6	10·7	10·0	10·4
Area of each plot	3·7 cents				2·8 cents				2·8 cents			

TABLE I B

Summary of the analysis of variance

Due to	1932-33			1933-34			1934-35		
	D. F.	Mean square	Value of *P*	D. F.	Mean square	Value of *P*	D. F.	Mean square	Value of *P*
Blocks	3	9·42	< ·01	3	13·0209	< ·01	2	1·7159	< ·01
Treatments	8	57·91	< ·01	8	114·9502	< ·01	8	65·7113	< ·01
Irrigations	2	220·68	< ·01	2	458·0430	< ·01	2	260·1990	Between ·05 & ·01
Spacings	2	7·32	< ·01	2	0·4146	> ·05	2	1·1309	
Irrigation and spacing	4	1·82	> ·05	4	0·6716	> ·05	4	0·7576	> ·05
Error	24	1·163	...	24	0·4743	...	16	0·2563	...

Comparison of mean values per plots

Item	Treatment means			Critical difference	Conclusion	Treatment means			Critical difference	Conclusions	Treatment means			Critical difference	Conclusions
	1 week	2 week	3 week			1 week	2 week	3 week			1 week	2 week	3 week		
Between irrigations	15·1	9·4	6·7	0·91	1 week > 2 week > 3 week	19·2	10·7	7·2	0·58	1 week > 2 week > 3 week	16·3	9·3	5·7	0·51	1 week > 2 week > 3 week
	4 in.	9 in.	B. cast			4 in	9 in.	B. cast			4 in.	9 in.	B. cast		
Between spacing	10·0	9·9	11·3	0·91	(4 in. = 9 in.) < Broad-cast	12·2	12·3	12·6	0·58	(4 in. = 9 in.) = Broad-cast	10·6	10·7	10·0	0·51	(4 in. = 9 in.) > Broad-casts
	Ridge	Bed				Ridge	Bed				Ridge	Bed			
Ridge vs. Bed .	10·0	11·3	...	0·79	Ridge < Bed	12·3	12·6	...	0·50	Ridge = Bed	10·6	10·0	...	0·44	Ridge > Bed

the differences in the frequencies of irrigations were more responsible for the differences than the changes in spacing, and that there was no interaction between spacing and irrigation frequency. As one should expect, 'one week' irrigation consumed the highest amount of water, while that done once in three weeks was the least, the differences between the three treatments being statistically significant in all the three years. When the effects of spacing were analysed, the behaviour was not consistent. In the first year broadcasted plots required more water, while in the third year both 4 in. and 9 in. spacings consumed more. In contrast to this, no difference was manifested between 4 in. and 9 in. spacings themselves. It is pointed out that the spacings by themselves were not responsible for the differential behaviour. Since 4 in. and 9 in. spacings were adopted in ridge method of planting as distinguished from broadcasting done in beds, it was plain that the method of irrigation had a greater influence for the causation of differences. Analysis of actual data for ridges vs. bed confirmed it. It was found that in the first year the bed method of irrigation consumed more water and in the third year the 'ridge' method used more. There was, however, one more point to be considered in this connection. In the first year (1932-33) the ridges were formed by mistake along the slope with the result the irrigations were more quickly done. This drawback robbed the data of that year of their significance. When the result of the other two years alone were scrutinized, it was found that ridge method of irrigation did not really reduce water consumption as is often claimed. On the other hand, it tended to increase as in 1934-35.

If the data of water consumed at each irrigation (Tables II A and II B) were examined, it was observed that the intervals between consecutive irrigations affected the quantity of water used each time ; the weekly irrigated plot utilized less water at each irrigation than that watered once in two or three weeks. This finding was to that extent in harmony with normal expectations. On closer scrutiny, it was noticed that the relationship between irrigation frequency and water consumption at each irrigation was not rectilinear. The average consumption in the plots irrigated once in two weeks was not double of that in the weekly irrigated, but was much less, the difference, however, being statistically significant. In the plots watered once in three weeks, the requirement was only a little more than in the two-week plots. In fact the differences were within the limits of statistical significance in all the years under study, showing thereby that the significant differences, obtained in the total quantities of water referred to previously, was more the effect of differences in the number of irrigations given than the actual water used each time.

The spacings had not caused significant differences in the average water consumption except in 1932-33, when the ridged plots recorded lower consumption, but much significance could not be attached to this finding for reasons mentioned already.

Examination of figures for individual irrigations revealed further that the water requirements tended to increase with the advance of summer (Fig. 1).

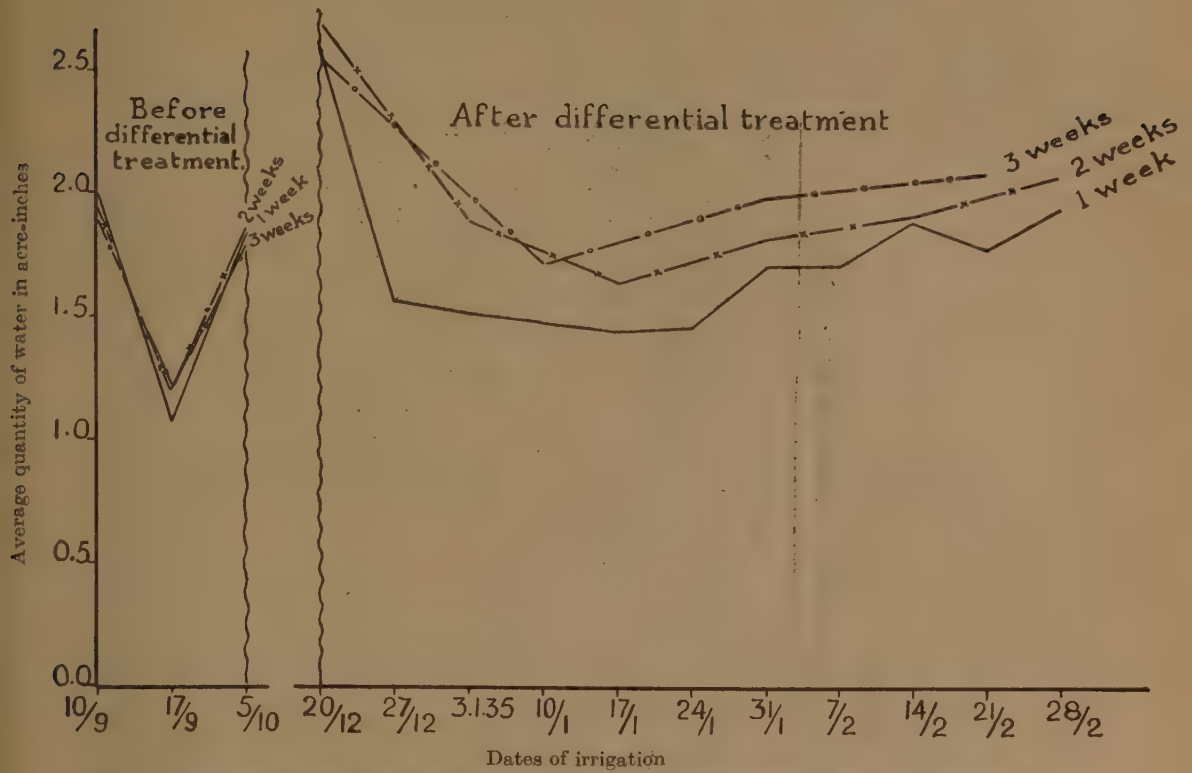

FIG. 1. Average quantity of water consumed by plots as the season advanced (1934-35)

(*b*) *Yields.*—The data of yields of the different treatments are given in Table III A. The statistical analysis of the results of the first year (Table III B) showed that the variance due to treatments was within the limit of significance. They were not therefore considered. On the examination of the data of the other two years it was seen that the unirrigated plots yielded only 489 and 474 lb. as against 759 and 641 lb. recorded on the average in the respective years by irrigated plots. These increases of 58 per cent and 35 per cent were statistically significant showing thereby the distinct advantage in yield got by irrigation.

A point of some interest was the lower increase obtained in 1934-35 which had to be ascribed to the alkaline nature of the soil.

Amongst the three irrigation frequencies, plots irrigated once a week recorded the highest yields, those watered once in two weeks less and those done in three weeks the least. But the differences between them were significant only in 1933-34, and that too only between the one and two week frequencies. In both years, the yields of plots irrigated once in three weeks were practically equal to those of the fortnightly irrigated plots. It was obvious from these that the present practice of irrigating once a fortnight could be safely put off to once in three weeks.

TABLE II A

Average quantity of water consumed at each irrigation in acre-inches

Frequency of irrigation	1932-33				1933-34				1934-35			
	Ridge		Bed	Average	Ridge		Bed	Average	Ridge		Bed	Average
	4 in.	9 in.	Broad-cast		4 in.	9 in.	Broad-cast		4 in.	9 in.	Broad-cast	
1 week	1·22	1·23	1·35	1·27	1·55	1·63	1·63	1·60	1·69	1·68	1·52	1·63
2 week	1·54	1·45	1·71	1·57	1·84	1·72	1·81	1·79	1·81	1·91	1·85	1·86
3 week	1·56	1·56	1·88	1·67	1·77	1·80	1·86	1·81	1·96	1·92	1·88	1·92
Average	1·44	1·41	1·65	1·50	1·72	1·72	1·77	1·73	1·82	1·84	1·75	1·80

TABLE II B

Summary of analysis of variance

Due to	1932-33			1933-34			1934-35		
	D. F.	Mean square	Value of *P*	D. F.	Mean square	Value of *P*	D. F.	Mean square	Value of *P*
Blocks	3	0·2127	< ·01	3	0·27750	< ·01	2	0·06840	< ·01
Treatments	8	0·1868	< ·01	8	0·04720	< ·01	8	0·06225	< ·01
Irrigations	2	0·5202	< ·01	2	0·16140	< ·01	2	0·21105	< ·01
Spacings	2	0·2052	< ·01	2	0·01080	> ·05	2	0·02025	> ·05
Irrigation and spacing	4	0·0109	> ·05	4	0·00830	> ·05	4	0·00885	> ·05
Error	24	0·0229	...	24	0·01015	...	16	0·00837	...

Comparison of mean values per plot

Item	Treatment mean			Critical difference	Conclusion	Treatment mean			Critical difference	Conclusion	Treatment mean			Critical difference	Conclusion
	1 week	2 week	3 week			1 week	2 week	3 week			1 week	2 week	3 week		
Between irrigations	1·27	1·57	1·67	0·13	1 week < 2 week = 3 week	1·60	1·79	1·81	0·08	1 week < 2 week = 3 week	1·83	1·86	1·92	0·09	1 week < 2 week = 3 week
	4 in.	9 in.	B. cast			4 in.	9 in.	B. cast			4 in.	9 in.	B. cast		
Between spacing	1·44	1·41	1·65	0·13	4 in. = 9 in. < B. cast	1·72	1·72	1·77	0·08	4 in. = 9 in. = B. cast	1·82	1·84	1·75	0·09	4 in. = 9 in. = B. cast
	Ridge	Bed				Ridge	Bed				Ridge	Bed			
Ridge vs. Bed	1·43	1·65	...	0·11	Ridge < Bed	1·72	1·77	...	0·07	Ridge = Bed	1·83	1·75	...	0·08	Ridge = Bed

TABLE III A

Summary of crude yields in lb. per acre

Treatment	1932-33				1933-34				1934-35			
	Ridge		Bed	Average	Ridge		Bed	Average	Ridge		Bed	Average
	4 in.	9 in.	Broad-cast		4 in.	9 in.	Broad-cast		4 in.	9 in.	Broad-cast	
1 week	648	663	605	639	880	848	814	847	806	524	733	688
2 week	634	528	554	572	763	704	696	721	756	429	673	619
3 week	485	648	598	577	706	742	679	709	743	561	546	616
Dry	..	518*	..	..	445	456	543	481	519	363	539	474
Average	589	613	586	596	699	687	683	690	706	469	623	599

* This figure was omitted in the analysis of variance as its inclusion made the analysis nonorthogonal.

Table III B

Summary of the analysis of variance

Due to	1932-1933			1933-34			1934-35		
	D. F.	Mean square	Value of *P*	D. F.	Mean square	Value of *P*	D. F.	Mean square	Value of *P*
Blocks	3	558·65	> ·05	3	3508·99	< ·01	2	532·02	> ·05
Treatment	8	652·77	> ·05	11	2066·35	< ·01	11	1508·13	Between ·05 and ·01
Between irrigation	2	717·99	> ·05	2	1800·91	< ·01	2	367·52	> ·05
Between spacings	2	123·39	> ·05	2	43·44	> ·05	2	4436·94	< ·01
Dry Vs irrigation	...	...	...	1	17882·26	< ·01	1	4848·12	< ·01
Irrigation Vs spacing	4	884·85	> ·05	6	193·14	> ·05	6	355·46	> ·05
Error	24	386·95	...	33	267·09	...	22	486·38	...

Comparison of mean values

Item	Treatment mean			Critical difference	Conclusions	Treatment mean			Critical difference	Conclusion	Treatment mean			Critical difference	Conclusion
	1 week	2 week	3 week			1 week	2 week	3 week			1 week	2 week	3 week		
Between irrigations	639	572	577	80	None significant	847	721	709	85	1 week > 2 week = 3 week	688	619	616	135	1 week = 2 week = 3 week
	4 in.	9 in.	B. cast			4 in.	9 in.	B. cast			4 in.	9 in.	B. cast		
Between spacings	589	613	586	80	Do.	699	687	683	73	4 in. = 9in. = B. cast	706	469	623	117	4 in. = B. cast > 9 in.
						Dry	Irri.				Dry	Irri.			
Dry Vs. irrigation	...	...	...	...	...	481	750	...	69	Irri. > dry	474	641	...	110	Irri. > dry
	Ridge	Bed				Ridge	Bed				Ridge	Bed			
Ridge Vs. bed	601	586	...	69	Do.	693	683	...	64	Ridge = Bed	588	623	...	101	Ridge = Bed

Changes in the method of irrigation were not able to cause marked differences in productivity. Variations in spacing, however, were able to cause significant differences in one year. In 1933-34, 4 in. and 9 in. spaced plots were practically equal, while in the next year the difference brought about by closer spacing was markedly favourable in the ridged plots. It could be deduced from the above that in alkaline soil, the use of a higher seed rate would prove more profitable.

(*c*) *Grader's valuation reports.*—The grader's valuation reports on these samples of Cambodia Co 2 grown with different amounts of irrigation in the three seasons, 1932-35 are given in Table IV.

(*d*) *Fibre test results.*—The results for mean fibre-length as found by the two methods, mean fibre-weight per inch and maturity percentages are given in Table V.

(*e*) *Spinning test results.*—The 1932-33 and 1933-34 samples were all passed through the porcupine, crighton (twice), hopper, scutcher (3 times), card, drawing (2 heads), slubber, inter, rover and spun from single hank roving on ring frame No. 1. The spinning master's report on each sample is given in the appendix . Only fibre tests were carried out on the 1934-35 samples as they were not available in sufficiently large quantities for spinning tests.

Discussion

(*a*) *Agricultural conditions and yield.*—It was made clear in the foregoing pages that under the conditions obtaining at the Cotton Breeding Station Coimbatore, irrigating Cambodia cotton from December onwards improved the yields, but the rate of increase was not directly proportional to the increase in the irrigational frequency. It would be, therefore, necessary to determine under such conditions the stage at which the irrigation would become unremunerative. The extra yields secured in the last two years as a result of irrigations were converted into monetary values and compared with cost incurred in irrigations, and the results were set out in Table VI. It was seen there that irrigation done once in three weeks was more remunerative than irrigating once a week or once in two weeks, in spite of their recording higher yields.

It could not, at the same time, be said that the three-week irrigation would always be the most paying, since it was not tested here whether a still lower frequency would result in a better monetary return. This point gained some strength from the performances of some treatments tested in 1935-36. A few experiments carried out in that year indicated that two irrigations timed once in early January and another in early February were as productive as irrigations given systematically every three weeks. These are to be tested further. Again it could not be said from the data presented here whether the quantity of water applied at each irrigation was the optimum. The consumption per irrigation varied in the present experiments from 1·22 acre-inches in 1932-33 to 1·96 acre-inches in 1934-35. This dosage would normally be considered as light. It might be that a heavier irrigation would alter the frequency, and thereby the ultimate gain to the cultivator as well.

It would be useful now to consider the observations recorded here in the light of the data obtained in 1935-36 on the movement of soil-moisture. In that year moisture determinations were made periodically in the first, second and third foot layers of irrigated and unirrigated plots. The data relating to dry plots and plots irrigated once in three weeks are given in Fig. 2 together with

TABLE IV A

Grader's report for Cambodia Co 2 for 1932-33 season

	4 inch spacing				9 inch spacing			Broadcast		
	Dry	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks
Contract valued under	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach
Class	Fine	Fine	Fine	Fine	Fine	Fine	Fine	Fine	Fine	Fine
Colour	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy
Staple length	1 in.	1 in.	31/32 in.	15/16 in.	1 in.	15/16 in.	31/32 in.	15/16 in.	1 in.	15/16 in.
Staple strength	Fair	Fair	Fair	Poor	Fair	Poor	Poor	Poor	Fair	Fair
Regularity	Fair	Fair	Fair	Fair	Fair	Poor	Fair	Poor	Fair	Fair
Valuation above or below contract rate	Rs. 60 on	Rs. 70 on	Rs. 60 on	Rs. 50 on	Rs. 70 on	Rs. 50 on	Rs. 55 on	Rs. 50 on	Rs. 70 on	Rs. 55 on
Basis	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200
Date of valuation	20-3-34	20-3-34	20-3-34	20-3-34	20-3-34	20-3-34	20-3-34	20-3-34	20-3-34	20-3-34
Remarks	...	...	...	Weak staple	...	Weak staple	Weak staple	Weak staple	...	...

Table IV B

Grader's report for Cambodia Co 2 for 1933-34 season

	4 inch spacing				9 inch spacing				Broadcast			
	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks
Contract valued under	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach	Broach
Class	Fine	About fine	About fine	About fine	About fine	About fine	About fine	About fine	About fine	About fine	About fine	About fine
Colour	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Creamy	Very Creamy	Creamy	Creamy	Creamy
Staple length	29/32 in.	7/8 in.	29/32 in.	29/32 in.	7/8 in.	29/32 in.	29/32 in.	29/32 in.	7/8 in.	13/16 in.	29/32 in.	13/16 in.
Staple strength	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Fair	Weak	Fair	Fair
Regularity	Fair	Irregular	Fair	Fair	Irregular	Irregular	Fair	Fair	Irregular	Irregular	Irregular	Irregular
Value above or below contract rate	Rs. 30 on	Rs. 45 on	Rs. 50 on	Rs. 50 on	Rs. 45 on	Rs. 50 on	Rs. 50 on	Rs. 50 on	Rs. 20 on	Rs. 35 on	Rs. 45 on	Rs. 35 on
Basis	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210	Rs. 210
Date of valuation	24-10-34	24-10-34	24-10-34	24-10-34	24-10-34	24-10-34	24-10-34	24-10-34	25-9-34	24-10-34	24-10-34	24-10-34
Remarks	...	...	...	...	...	Harsh	...	...	...	...	...	...

TABLE IV C

Grader's report for Cambodia Co 2 for 1934-35 season

	4 inch spacing				9 inch spacing				Broadcast			
	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks
Contract valued under	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936	Broach A/M 1936
Class	Fine to superfine	Fine to superfine	Fine to superfine	Fine to superfine.	Nearly superfine	Fine to superfine	Fine to superfine	Fine to superfine	Fine to superfine	Superfine	Superfine	Superfine
Colour	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white	Creamy-white
Staple length	3/4 in.	13/16 in.	13/16 in.	Nearly 7/8 in.	7/8 in.	7/8 in.	7/8 in.	7/8 in.	7/8 in.	7/8 in.	7/8 in.	13/16 in.
Staple strength	Moderate	Moderate	Slightly Better than dry sample	Good	Good	Good	Good	Good	Good	Good	Good	Moderate
Regularity	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular	Regular
Value above or below contract rate	Rs. 55 on	Rs. 60 on	Rs. 65 on	Rs. 70 on	Rs. 68 on	Rs. 70 on	Rs. 72 on	Rs. 65 on	Rs. 70 on	Rs. 70 on	Rs. 67 on	Rs. 65 on
Basis	Rs. 200	Rs. 220	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200	Rs. 200
Date of valuation	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35	10-9-35
Remarks	...	...	Slightly yellow stain	More silky than previous tender	Sample knotty	Silky style	...	Sample somewhat knotty and neppy	...	Knotty	Slightly wasty	Not well ginned; staple wasty

TABLE V A

Fibre particulars for Cambodia Co 2 for 1932-33 season

1. Fibre-length distribution (Balls Sorter): Mean group-length in eighths of an inch	Percentage									
	4 inch spacing				9 inch spacing			Broadcast		
	Dry	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks	1 week	2 weeks	3 weeks
2	...	...	...	...	0·9	...	...	...	...	1·5
3	2·4	1·8	1·5	2·1	2·0	2·3	2·2	2·1	1·4	2·3
4	3·6	3·6	3·6	3·9	3·2	3·7	4·0	3·4	4·7	3·8
5	6·8	6·0	6·7	6·6	6·6	7·0	6·6	6·5	5·7	7·1
6	10·9	10·6	12·8	11·2	12·1	15·9	11·9	11·7	13·7	10·9
7	21·1	21·2	24·1	22·1	22·7	24·8	22·3	21·7	18·9	19·7
8	27·8	28·3	33·3	29·2	27·3	25·7	28·1	29·9	29·7	27·0
9	19·9	19·7	14·9	17·4	17·5	14·5	19·7	18·5	21·2	19·4
10	6·3	6·8	3·1	5·0	6·3	6·1	5·2	4·5	4·7	6·8
11	1·2	2·0	...	2·5	1·4	...	...	1·7	...	1·5
2. Fibre-length (inch):—										
(*a*) By Balls Sorter	0·93	0·94	0·91	0·93	0·92	0·90	0·92	0·93	0·93	0·93
(*b*) By Baer Sorter	0·90	0·91	0·93	0·90	0·90	0·93	0·90	0·94	0·92	0·92
3. Fibre-weight per inch (millionths of an oz.)	0·140	0·133	0·138	0·141	0·147	0·137	0·145	0·137	0·140	0·152
4. Maturity test results:—										
(*a*) Mature	53	61	58	65	54	58	56	65	58	67
(*b*) Half-mature	13	12	12	10	14	15	11	12	12	11
(*c*) Immature	34	27	30	25	32	27	33	23	30	22

TABLE V B

Fibre particulars for Cambodia Co 2 for 1933-34 season

	Percentage											
1. Fibre-length distribution (Balls Sorter) :—	4 inch spacing				9 inch spacing				Broadcast			
Mean group-length in eighths of an inch	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks
2	1·5	...	1·1	1·2	1·1	0·9	1·0	1·0	1·0	...	1·5	...
3	2·6	1·6	1·9	2·0	2·2	2·3	2·3	1·9	1·4	1·1	2·5	3·5
4	3·7	4·0	2·9	2·3	3·8	3·9	3·6	3·1	3·2	3·8	3·8	4·2
5	5·9	7·8	4·8	5·4	7·9	6·7	6·3	6·8	5·4	6·6	6·4	7·3
6	11·5	10·4	8·6	8·1	11·2	10·8	10·4	11·8	10·1	9·6	13·2	12·9
7	23·8	17·1	18·0	17·3	24·3	19·5	19·1	22·3	18·7	19·2	22·7	22·3
8	31·4	28·1	32·6	31·5	27·0	28·8	30·9	30·6	29·7	27·4	32·3	30·1
9	14·4	23·8	23·3	24·0	16·9	19·5	20·0	16·5	22·3	23·9	14·5	16·2
10	4·1	5·9	5·7	6·6	5·6	6·3	5·0	5·0	7·0	7·3	3·1	3·5
11	1·1	1·3	1·1	1·6	...	1·3	1·4	1·0	1·2	1·1	...	...
2. Fibre-length (inch) :—												
(*a*) By Balls Sorter	0·91	0·94	0·95	0·96	0·91	0·93	0·93	0·92	0·95	0·95	0·89	0·90
(*b*) By Baer Sorter	0·92	0·92	0·94	0·96	0·94	0·91	0·90	0·93	0·92	0·94	0·90	0·92
3. Fibre-weight per inch	0·134	0·137	0·141	0·136	0·134	0·138	0·131	0·138	0·130	0·138	0·137	0·135
4. Maturity test results :—												
(*a*) Mature	59	56	63	60	62	61	53	62	58	61	60	57
(*b*) Half-mature	10	14	15	12	13	12	16	13	15	13	13	13
(*c*) Immature	31	30	22	28	25	27	31	25	7	26	27	30

TABLE V C

Fibre particulars for Cambodia Co 2 for 1934-35 season

1. Fibre-length distribution (Balls Sorter) :— Mean group-length in eighths of an inch	Percentage											
	4 inch spacing				9 inch spacing				Broadcast			
	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks
2	1·1	...	0·6	0·7	0·8	...	0·8	0·6	1·0	...	...	1·0
3	1·6	3·1	3·3	2·1	1·6	1·3	1·9	3·0	1·4	1·5	2·0	2·3
4	2·7	4·4	4·1	3·2	4·1	2·6	3·3	5·0	3·5	4·0	2·3	4·2
5	4·6	6·1	6·5	6·3	7·5	5·3	6·2	7·9	8·0	8·3	6·2	6·2
6	9·8	11·6	11·1	11·6	12·7	11·0	12·0	14·7	19·0	15·4	14·1	15·6
7	21·9	26·9	22·2	22·4	29·4	30·2	24·0	24·4	34·2	27·1	24·5	28·3
8	29·3	32·1	32·6	33·7	33·3	33·2	29·8	27·9	23·9	28·3	31·0	31·7
9	18·7	13·7	16·3	15·8	9·0	13·4	16·9	12·7	7·3	12·0	15·0	9·7
10	7·6	2·1	3·3	3·5	1·6	3·0	4·3	3·2	1·7	3·4	4·9	1·0
11	2·7	...	...	0·7	...	...	0·8	0·6	...	...	...	...
2. Fibre-length (inch) :—												
(*a*) By Balls Sorter	0·95	0·90	0·90	0·92	0·88	0·92	0·92	0·88	0·86	0·89	0·92	0·87
(*b*) By Baer Sorter	0·92	0·88	0·90	0·94	0·88	0·90	0·88	0·88	0·90	0·86	0·88	0·90
3. Fibre-weight per inch (millionths of an oz.)	0·128	0·133	0·136	0·133	0·136	0·138	0·136	0 153	0·132	0·146	0·147	0·127
4. Maturity test results :—												
(*a*) Mature	44	48	40	41	46	45	46	49	50	54	45	39
(*b*) Half-mature	29	23	27	27	21	21	30	23	20	19	22	21
(*c*) Immature	27	29	33	32	33	34	24	28	30	27	33	40

TABLE VI

Treatment	1933-34				1934-35			
	Increase in the weight of *kapas* over dry plot	Value of the increase	Cost of irrigation	Profit or loss	Increase in the weight of *kapas* over dry plot	Value of the increase	Cost of irrigation	Profit or loss
	lbs.	Rs.*	Rs.**	Rs.	lbs.	Rs.*	Rs.**	Rs.
1 week	366	39	42	—3	214	23	42	—19
2 weeks	240	24—26	21	5	145	16	21	—5
3 weeks	228	24	14	10	142	15	14	1

* *Kapas* values at Rs. 30 per 280 lbs.
** Cost of single irrigation was taken at Rs. 3-8-0.

dates of irrigation and rainfall. It would be seen there that in the first foot, the fluctuations were wide and moisture levels were very much higher than in those in the unirrigated plots. They were high soon after each irrigation and least just prior to the irrigation. In the case of the readings of the second foot the variations were within narrow limits of the unirrigated plots and those of the third foot were practically identical with the second. It was evident from these that the irrigations affected mostly the first foot of soil. In other words it would appear that the chief purpose served by irrigation in Cambodia cotton would seem to be to preserve the moisture contents in the second and third foot layers and this function could be efficiently served by the irrigations given once in three weeks.

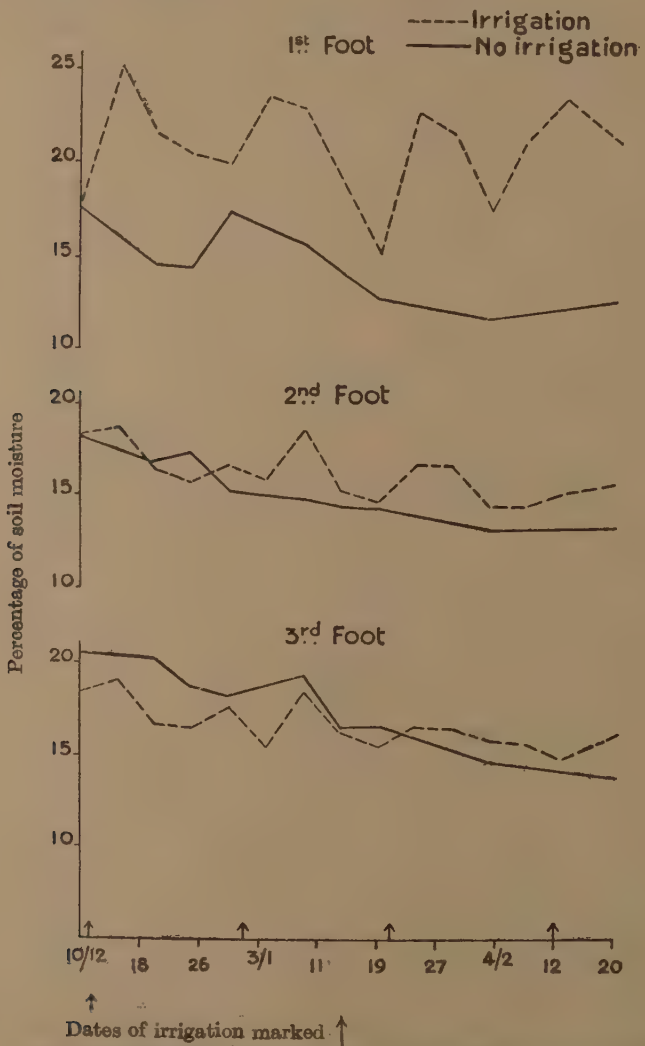

FIG. 2. Percentage of soil-moisture (irrigation experiment 1935-36)

(*b*) The results of the various fibre and spinning tests for these two seasons are summarized in Table VII.

TABLE VII

Particulars of irrigation experiments samples, 1932-33 and 1933-34

Coimbatore

Sample No.		Irrigation		Fibre-length (in.)		Fibre-weight per inch (10^{-6} oz.)		Maturity per cent		Total loss per cent		Neps per yard		Highest standard warp counts	
1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34
							9 in. spacing								
2120	2423	Once a week	Once a week	0·91	0·92	0·147	0·138	54	61	18·8	20·6	2·8	2·7	30	28
2123	2426	Once in 2 weeks	Once in 2 weeks	0·92	0·92	0·137	0·131	58	53	17·6	22·1	1·6	4·0	32	29½
2130	2429	Once in 3 weeks	Once in 3 weeks	0·91	0·92	0·145	0·138	56	62	18·3	19·4	2·9	4·0	29	31
2133	2432	Dry grown	Dry grown	0·92	0·92	0·140	0·134	53	62	18·8	24·5	3·3	4·8	32	29
							4 in. spacing								
2121	2424	Once a week	Once a week	0·92	0·93	0·133	0·137	61	56	17·0	20·9	1·5	2·5	30	28
2124	2427	Once in 2 weeks	Once in 2 weeks	0·92	0·94	0·138	0·141	58	63	15·9	21·7	1·5	4·3	32	29
2131	2430	Once in 3 weeks	Once in 3 weeks	0·92	0·96	0·141	0·136	65	60	18·4	19·5	3·2	4·7	30½	28
2133	2433	Dry grown	Dry grown	0·92	0·92	0·140	0·134	53	59	18·8	24·5	3·3	5·4	32	30
							Broadcast								
2122	2425	Once a week	Once a week	0·94	0·94	0·137	0·138	65	61	16·2	21·3	1·6	4·3	28	27
2125	2428	Once in 2 weeks	Once in 2 weeks	0·92	0·90	0·140	0·137	58	60	17·8	20·2	1·4	4·5	32	29
2132	2431	Once in 3 weeks	Once in 3 weeks	0·92	0·91	0·152	0·135	67	57	15·9	18·9	1·4	4·3	32	28½
2133	2434	Dry grown	Dry grown	0·92	0·94	0·140	0·130	53	58	18·8	25·2	3·3	5·3	32	29

TABLE VII—*contd.*

Percentage differences based on the dry-grown sample

Sample No.		Irrigation		Fibre-length (in.)		Fibre-weight per inch (10^{-6} oz.)		Maturity per cent		Total loss per cent		Neps per yard		Highest standard warp counts	
1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34	1932-33	1933-34
							9 in. spacing								
2120	2423	Once a week	Once a week	99	100	105	103	1	—1	...	—3·9	85	56	94	97
2123	2426	Once in 2 weeks	Once in 2 weeks	100	100	98	98	5	—9	—1·2	—2·4	48	83	100	102
2130	2429	Once in 3 weeks	Once in 3 weeks	99	100	104	103	3	...	—0·5	—5·1	88	83	91	107
2133	2432	Dry grown	Dry grown	100	100	100	100	...	...	...	...	100	100	100	100
							4 in. spacing								
2121	2424	Once a week	Once a week	100	101	95	102	8	—3	—1·8	—3·6	45	46	94	93
2124	2427	Once in 2 weeks	Once in 2 weeks	100	102	99	105	5	4	—2·9	—2·8	45	80	100	97
2131	2430	Once in 3 weeks	Once in 3 weeks	100	104	101	101	12	1	—0·4	—5·0	97	87	95	93
2133	2433	Dry grown	Dry grown	100	100	100	100	...	...	...	...	100	100	100	100
							Broadcast								
2122	2425	Once a week	Once a week	102	100	98	106	12	3	—2·6	—3·9	48	81	88	93
2125	2428	Once in 2 weeks	Once in 2 weeks	100	96	100	105	5	2	—1·0	—5·0	42	85	100	100
2132	2431	Once in 3 weeks	Once in 3 week	100	97	109	104	14	—1	—2·9	—6·3	42	81	100	98
2133	2434	Dry grown	Dry grown	100	100	100	100	...	...	...	...	100	100	100	100

The following conclusions are drawn from the results.

(1) *Mean fibre-length.*—The values of mean fibre-length of the 1932-33 samples are very nearly constant and do not show any significant variation with either the irrigation treatment or the different spacings. In 1933-34 while no significant differences in mean length are observed for samples grown with 9 in. spacing, for samples grown with 4 in. spacing the irrigated samples are found to be slightly longer than the unirrigated one, while in the case of the broadcast seed samples the mean fibre-length of the two irrigated samples is less than that of the unirrigated samples. These differences, however, are small and most probably within the sampling errors. It may, therefore, be concluded from the results of these tests, that neither the frequency of irrigation nor the different modes of sowing—each within the limits of this experiment—had any appreciable effect on the mean fibre-length of this cotton.

(2) *Fibre-weight per inch.*—The differences between the values of fibre weight per inch of the irrigated and the unirrigated samples are small. However, in a majority of cases the irrigated samples are found to have a somewhat higher hair weight per inch than the unirrigated samples. On the other hand, the mode of sowing had produced very little change in the hair weight per inch. We may, therefore, conclude that while the hair weight per inch of this cotton is independent of the mode of sowing employed in these tests, it shows a tendency to increase with the amount of irrigation given to the crop. In other words, with a more plentiful supply of water, there is a slightly greater deposition of cellulose in the fibre.

(3) *Maturity count.*—The results of the maturity test show that the irrigated samples contain, on the whole, a somewhat higher percentage of mature fibres than the unirrigated samples. The mode of sowing, on the other hand, has not affected the maturity count of this cotton in any way, as identical values are obtained for three unirrigated samples sown in different ways. These results are in line with those obtained for hair weight per inch, and show that the effect of plentiful supply of water is to increase the percentage of mature hairs in this cotton.

(4) *Waste losses.*—The results for the total loss suffered by the samples up to the spinning point are interesting as they show that in 17 out of 18 cases the irrigated samples gave lower waste losses as compared with the unirrigated samples, in the remaining case the losses for the two types of samples were equal, while in no case did the total loss of the irrigated sample exceed that of the unirrigated sample. The differences between the waste losses of the two types of samples are small in 1932-33, but in the following season they lie between 2 per cent and 6 per cent, the lowest loss in each of the three sets of samples corresponding to 9 in. spacing, 4 in. spacing and broadcast seed, being given by the sample which was irrigated once in three weeks. The mode of sowing, on the other hand, had practically no effect on the total loss. We may, therefore, conclude that while the total loss sustained by this cotton in the blow room and the card room is independent of the mode of sowing, it is somewhat less if the cotton is grown under irrigation.

(5) *Spinning performance.*—In 11 out of 18 cases the spinning performance of the irrigated samples is slightly lower than that of the unirrigated samples, in five cases it is equal, while only in two cases it is slightly better. Thus, on the whole, the yarns spun from the irrigated samples gave lower strength as

compared with those spun from the unirrigated samples. The differences, however, in the performance of the two types of samples are quite small and are most probably due to the effect of irrigation on the hair weight per inch of this cotton. Other factors being the same, a coarse cotton would give a lower performance primarily because of the fewer fibres present in a cross-section of the yarn of the same count as spun from a relatively finer cotton. It should finally be stated that the spinning performance was found to be unaffected by the mode of sowing of the samples employed in this experiment.

(6) *Neps per yard.*—The yarns spun from the unirrigated samples were somewhat neppy in 1932-33 and neppy in the following seasons. In both seasons, growing the samples under irrigation reduced the neppiness of the yarns, in some cases by more than 50 per cent. The mode of sowing, on the other hand, had practically no effect on the degree of neppiness of the yarns. We may, therefore, conclude that while the yarn-neppiness of this cotton is independent of the mode of sowing adopted in this experiment, it is appreciably reduced by growing the cotton under irrigation. This observation agrees very well indeed with the results of an investigation carried out at the Technological Laboratory and described in Technological Bulletin Series B, No. 20 which showed that the degree of neppiness of a cotton was significantly correlated to the percentage of mature hairs present in it. In the present case irrigation increased the proportion of mature hairs and hence improved the appearance of the yarn as regards its neppiness.

Fibre-test results, 1934-35

The results of mean fibre-length, fibre-weight per inch and maturity count determination for the different systems of irrigation and different spacings are summarized in Tables IX to XI. The following conclusions are drawn from a consideration of these results.

(1) *Fibre-length.*—On the whole, the system of irrigation had very little effect on the mean staple length. This agrees with the results of the previous two seasons. The effect of spacing was a little more marked, the 4 in. spacing giving, on the whole, better results than the 9 in. spacing, which in its turn gave better results than broadcast sowing.

(2) *Fibre-weight.*—The irrigated samples gave somewhat higher values than the unirrigated samples. This agrees with the results of the previous seasons, where it was found that the effect of plentiful supply of water by irrigation was to deposit more cellulose in the fibre. The differences between the various irrigated samples are non-significant. The samples grown with 4 in. spacing are, on the whole, somewhat finer than those grown either with 9 in. spacing or from broadcast sowing.

(3) *Fibre-maturity.*—The samples which were irrigated once a week had, on the whole, a higher percentage of mature hairs than the others. This again agrees with the observation for the earlier seasons which recorded a higher percentage of mature hairs for the irrigated samples. As regards spacings, however, there is practically no difference between the 9 in. spacing and the broadcast sown samples, but the samples grown with 4 in. spacing had, on the whole, a lower percentage of mature fibres.

Summary

A complex experiment consisting of two methods of irrigation, three irrigation frequencies and two spacings, was conducted on Cambodia cotton for

Table IX

Fibre-length (inches)

Spacings	Intervals of irrigation			
	1 week	2 weeks	3 weeks	Dry
4 in.	0·89	0·90	0·93	0·94
9 in.	0·91	0·90	0·88	0·88
Broadcast	0·88	0·90	0·88	0·88

Table X

Fibre-weight per inch (millionth of an ounce)

Spacings	Intervals of irrigation			
	1 week	2 weeks	3 weeks	Dry
4 in.	0·133	0·136	0·133	0·128
9 in.	0·138	0·136	0·153	0·136
Broadcast	0·146	0·147	0·127	0·132

Table XI

Maturity (per cent)

Spacings	Intervals of irrigation							
	1 week		2 weeks		3 weeks		Dry	
	Mature	Immature	Mature	Immature	Mature	Immature	Mature	Immature
4 in.	48	29	40	33	41	32	44	27
9 in.	45	34	46	24	49	28	46	33
Broadcast	54	27	45	33	39	40	50	30

three seasons at Cotton Breeding Station, Coimbatore. The lint produced in each treatment was examined for fibre properties and spinning performance at the Technological Laboratory, Bombay. The results pointed out that :—

(*a*) Irrigating Cambodia after December improved the yield definitely.

(*b*) Irrigating once a week tended to give highest yields ; but the increase obtained was not of such a magnitude as to pay for the extra expense involved in giving additional irrigations.

(*c*) Irrigating once in three weeks was most profitable.

(*d*) The quantity of water consumed at each irrigation by 'one week' plots was distinctly less than in plots irrigated once in three weeks.

(*e*) On a level field there was little difference in the consumption of water between ridge and bed system of irrigation.

(*f*) Variations in the density of plant population had no effect on water consumption.

(*g*) Neither the frequency of irrigation nor the different modes of sowing—each within the limits of this experiment—had any appreciable effect in 1932-33 and 1933-34 on the mean fibre-length of this cotton. In 1934-35 season, however, the 4 in. spacing gave, on the whole, somewhat higher mean length than 9 in. spacing, which, in its turn, gave slightly better results than broadcast sowing.

(*h*) While the hair-weight per inch of this cotton is practically independent, in 1932-33 and 1933-34 seasons, of the mode of sowing employed in these tests, it shows a tendency to increase with the amount of irrigation given to the crop. In other words, with a more plentiful supply of water, there is a greater deposition of cellulose per unit length in the fibre. In 1934-35 season the samples grown with 4 in. spacing are proved, on the whole, to be somewhat finer than those grown either with 9 in. spacing or from broadcast seed.

(*i*) Irrigated samples contain, on the whole, a higher percentage of mature fibres as compared with the unirrigated samples. The mode of sowing, on the other hand, did not affect the maturity count of this cotton in any way in 1932-33 and 1933-34 seasons. In 1934-35, however, the samples grown with 4 in. spacing contained a lower percentage of mature hairs.

(*j*) While the total loss sustained by this cotton in the blow room and the card room was independent of the mode of sowing, it was somewhat less when the cotton was grown under irrigation.

(*k*) While the yarn neppiness of this cotton is independent of the mode of sowing adopted in this experiment, it is appreciably reduced by growing it under irrigation. This agrees very well with an earlier conclusion of the laboratory that the degree of neppiness of a cotton is significantly correlated to the percentage of mature hairs present in it.

(*l*) The spinning performance was found to be unaffected by the mode of sowing of the samples employed in this experiment. The yarns spun from the irrigated samples, on the whole, gave lower strength as compared with those spun from the unirrigated samples. The difference, though small, is most probably due to the effect of irrigation on the hair-weight of this cotton.

ACKNOWLEDGEMENT

The authors take this opportunity to thank Dr S. Kasinatha Ayyar and Mr K. L. Ramakrishna Rao for help rendered during work on these experiments.

APPENDIX

Spinning master's reports

	4 inch spacing				9 inch spacing				Broadcast			
	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks	Dry	1 week	2 weeks	3 weeks
1932-33												
Colour						Creamy-white ; brightish						
Cleanliness							Clean					
Feel	...	Soft ; smooth	Good ; smooth	Good	...	Soft ; smooth	Smooth and bodied	Good	Good ; smooth	Smooth and bodied	Smooth and bodied	Good ; smooth
Ginning and neppiness	...	Well-ginned	Well-ginned.	Well-ginned	...	Well-ginned	Well-ginned	Well-ginned	Well-ginned	Well-ginned	Well-ginned	Well-ginned
Card sliver							Clean					
Card-web	...	Good	Even and nep-free	Even and nep-free	...	Good	Even and nep-free	Even and nep-free.	Even and nep-free	Even and nep-free	Even and nep-free	Even and nep-free
1933-34												
Colour						Creamy-white ; brightish						
Cleanliness	Clean	Very clean.	Clean	Clean	Clean	Very clean	Clean		...	...	...	...
Feel	Soft ; smooth	Good-bodied	Good	Good	Soft ; smooth.	Good ; bodied	Good	Good	Soft ; smooth	Good	Good	Good
Ginning and neppiness	A little knotted	Well-ginned	Fairly well-ginned	Fairly well-ginned	A little knotted	Well-ginned	Fairly well-ginned.	Fairly well-ginned	A little knotted	Well-ginned.	Fairly well-ginned	Fairly well-ginned
Card-sliver							Clean					
Card-web	A little cloudy ; some-what neppy	Cloudy ; slightly neppy	Even ; some-what neppy	Even ; some-what neppy	A little cloudy ; some-what neeppy	Cloudy ; slightly neppy	Even and some-what neppy	Even and some-what neppy	A little cloudy ; some-what neppy	Good	Even and some-what neppy	Even and some-what neppy

INDIGENOUS AND EXOTIC COTTONS OF IRAN

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(Received for publication on 6 April 1939)

(With two text-figures)

Introduction

IN connection with the improvement of *herbaceum* cotton in India by breeding it was considered that it would be worth collecting early and long stapled types of *herbaceums* from Iran. A scheme to undertake a survey of the Iran cotton was therefore suggested to the Indian Central Cotton Committee in 1935 and, when it was sanctioned in 1936, I was deputed for the work. I left Indore on August 31, 1936 and entered the Iranian territory at Zahidan on September 9, 1936. The actual survey took a period of eight weeks. The only information available about the cottons in Iran was a record by the Russian worker, Cheranykaroskya [1930], who had described the great variability of *herbaceum* cottons in Siestan and Khorasan.

Cotton areas visited and their characteristics

The whole journey in Iran, of about 4,000,miles was done in a car, excepting a few impassable places in Siestan and Khorasan where it was performed on horseback. In all 56 different localities were visited and 1,500 single plant samples of *kapas* and 165 samples of soil were collected. The cotton areas visited have been divided into three regions, eastern, western and northern and their description is given below :—

The eastern region includes Zabol (Siestan) and the area from Zahidan to Meshhad district. It is for the most part a plain sloping from an elevation of 4,000 ft. in the west to 1,500 ft. above sea level in the east. The fertile areas under cottons are interspersed with large salt areas. The soil in the cultivated areas is for the most part light sandy loam of the loess kind and, excepting Zabol, is predominantly under *herbaceum* cottons. The cultivated parts have coarse sand with small fragments of rocks on the surface. The colour of the soil varies from grey to brown. Rainfall in the western part of this region averages about 9 in. while in the eastern 4 in. only. The range of temperature at Meshhad is from 15° F. to 76° F., the average being 56·3.

The northern region consists of a strip of very fertile land, beginning from Sabzavar and extending as far as Nowshehr in Mazandaran on the Caspian. The soil from Neishapoor to Sudkhar is heavy sandy loam and is predominantly under *hirsutum* cottons. The region from Davarzan to Semnan has for most of the parts light loam of the loess kind and is also under *herbaceums*. The uncultivated regions are sandy. In the Mazandaran area bordering on the Caspian Sea, the soil is again heavy sandy loam, the cotton growing there being exclusively of *hirsutum* type. The colour of the soil varies from grey

to brown excepting in Mazandaran area where it is black or dark brown. Mazandaran has an yearly rainfall of 50 in. to 80 in. The range of temperature at Tehran is from 30 to 111° F. and the average 60·4. The rainfall in Tehran varies from about 9 in. to 10 in.

FIG. 1. Map of Iran showing cotton areas visited

The western section comprises the whole of the area from Tehran to Shiraz. The cultivated areas are far apart. Districts of Tehran, Qom, Kashan, Isfahan, Yazd and Shiraz are very fertile and have vast areas under cotton. The intervening regions are barren and sandy. The way from Shiraz to Bushire is extremely hilly.

The soil of the cultivated areas from Tehran to Morchikhat is heavy sandy loam. From Anoushirwan to Yazd the soil is light loam, with the exception of Isfahan which has heavy sandy loam. The cotton growing in the western region is mostly the *herbaceum* type including the heavy soil areas like those of Isfahan and those between Tehran and Morchikhat. The soil of the uncultivated areas from Anoushirwan to Shiraz is highly saline. The colour of the soil for most of the parts varies from grey to brown, it being dark brown in

Shiraz. The average temperature and rainfall for Isfahan, Shiraz and Bushire are given below :—

——	Maximum °F.	Minimum °F.	Average	Rainfall (in.)
Isfahan	106	—3	58·0	5·4
Shiraz	113	21	65·0	?
Bushire	109	75	91·0	13·4

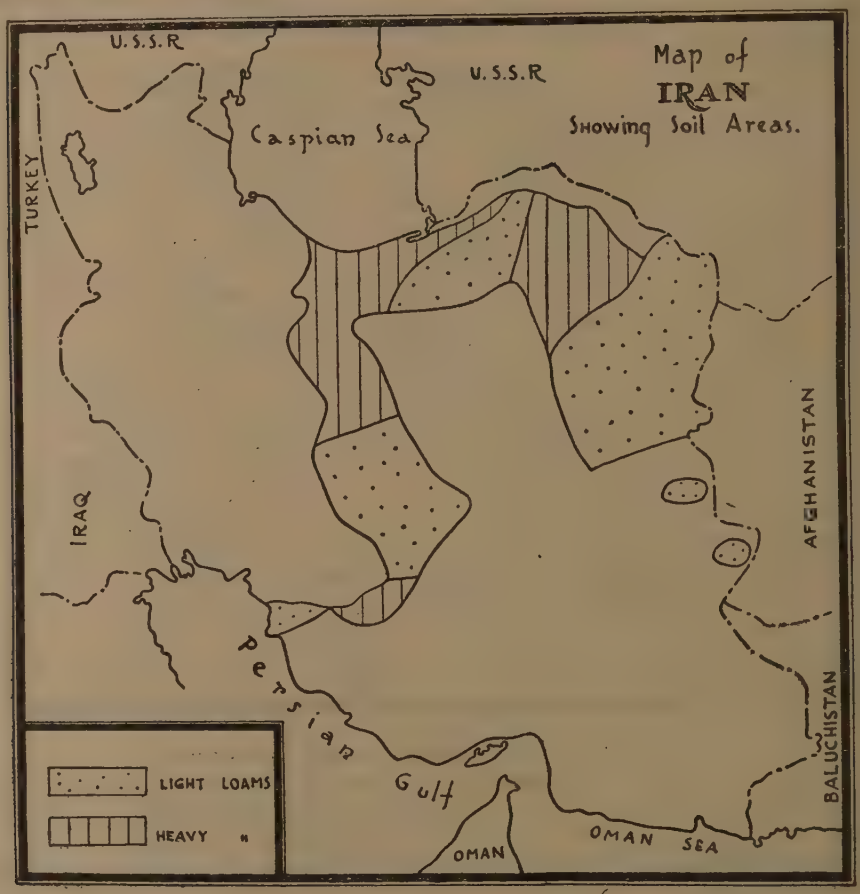

Fig. 2. Map of Iran showing soil areas

Agricultural details of cotton growing

The sowing time for cotton all over Iran extends from March to May except in South Iran where it is earlier, viz. the first three weeks of February. The seed is usually broadcast though sowing in lines with bullock-drawn drills is coming into vogue. A seed rate of 30 to 40 lb. per acre is used in the case of a broadcast crop, while about 15 lb. suffices for line sowing. Except in

Mazandaran area which receives a rainfall of 50-80 inches during the cotton season, cotton all over Iran is irrigated. The number of irrigations varies from four to six depending on the availability of water.

The crop starts flowering from the beginning of May and goes on until the end of July, roughly about 80 days after sowing. The picking of cotton is carried out from July to October, the first picking commencing about 60-65 days after the beginning of the flowering phase. In order to hasten maturity it is a general practice in Iran to strip the plants of its leaves and also to top them at any stage between bud and boll formation. The yield of seed cotton is said to average between 400 and 600 lb. per acre although the cotton statistics for 1932-33 records it as over 700 lb. for that year.

The Entomological Department at Tehran has indentified the undermentioned pests and recorded their comparative incidence.

Pests which cause very heavy damage :—

a. *Heliothis obsoleta* (Bollworm) 30 per cent damage in Mazandaran.
b. *Aphis gossypii* and *Aphis laburni* (plant lice) 20 per cent damage in Khorasan and Mazandaran.
c. *Oxycaraenus hyalinipennis* (cotton bug)
d. *Dysdercus delauneyi* (stainer) causes damage in the province of Faras.
e. *Nezara viridula* (shield bug) causes damage along the Persian Gulf.
f. *Cicadetra Ochreata* causes damage in North Iran.
g. *Acyrothosyphon gossypii* causes damage in North Iran.

Pests which cause moderately heavy damage :—

h. *Gryllus desertus* (cricket)—North Iran.
i. *Gryllotalpa gryllotalpa* (mole cricket) —North Iran.
j. *Lethrus*—Mazandaran.
k. *Epicanta erythrocephala* (Beetle)—Tehran.
l. *Heliothis peltigera* (Bollworm)—North Iran.
m. *Plusia gamma* (leaf eater)—Tehran and Shahrud.
n. *Botinoderes punctiventris*—Tehran.
o. *Monastria inermis*—Tehran.
p. *Oedalaeus decorus*—North Iran.
q. *Anacridium aegyptium*—South Iran.
r. *Elateridae* (wire worms)—two species—Varamin.

It would be seen that most of the above pests and diseases are common in North Iran which is predominantly the American cotton area. The American cottons suffered heavily from pests and diseases, while the indigenous ones were comparatively free.

Cotton industry in Iran

Cotton cultivation in Iran has recently been organized, having become a State monopoly. The company controlling the cotton cultivation is known as ' Shirkat-i-Sahami Pamba ' consisting of shareholders from amongst the Iranees. It is financed by the Agricultural Bank of Iran which is a branch of the National Bank of Iran established in 1930 and has an authorized capital of 50,000,000 *rials* or £625,000 approximately. Both the Company and the Bank have branches all over the country. The Company sells seeds to

cultivators at a nominal rate. The cultivators should sell the produce to the Company only and the latter have an exclusive right to export it or sell it in the country. As cotton picking ends by October, the ginning factories work from November till the end of March, the export time being from December to May. According to cotton statistics of 1932-33 the total area under cotton and the total yield are about 1·5 million acres and 2·9 million bales respectively (details given in Appendix I).

There was a project to increase the area to twice its size. A circular was issued by the Shah of Iran, forbidding the cultivation of opium poppy and to grow cotton in its place. In 1934, the Province of Khorasan (the largest cotton-growing province in Iran) produced 60,000 bales of 250 lb. each of cotton (47,000 bales of the indigenous cotton, 10,000 bales of ' Pure American cotton ' and 3,000 of ' Felistani '). The market rates given below were those offered by Russian buyers. They bought delivered on the frontier near Ashkabad at 42/- *rials* a pood nett (Rs. 6/9 for 36 lb.) for local cotton, at 62/- *rials*, (Rs. 9/11) for American and at 72/- *rials* (Rs. 11/4) for Felistani cottons (1 pood=36 lb. approximately, 1 *rial*=1/6·4 rupee). The packing charges were about 10/- *rials* (Re. 1/9) a bale.

Indigenous cottons

The indigenous cottons of Iran known locally as *Mahali*, *Rasmi* or *Bumi*, belong to *G. herbaceum* var. *typicum* [Hutchinson and Ghose, 1937]. The various forms as found during the survey can be grouped as follows :—

(*a*) Plants 1 ft.-5 ft. and vigorous, leaves green to deep green, bolls big and rounded with small beak, bolls opening slightly when ripe [*c. f.* Grade 4, Hutchinson and Ramiah, 1938], lint white, soft, fine and long, predominantly late. Only earlier plants ready for picking at the time of the visit.

(*b*) Intermediate between (*a*) and (*c*)

(*c*) Plants 1-2½ ft., weak, leaves green to pale green, bolls small and not so rounded as in (*a*), with prominent beak and opening widely when ripe [c. f. Grade 2, Hutchinson and Ramiah, 1938]. Lint white, dull white, *khaki* or deep *khaki*, coarse and short. Predominantly early, almost all plants ready for picking at the time of the visit. Considerable variation was found in the colour of the leaves and therefore it should not be regarded of any taxonomic importance.

Distribution of the above three types

	Locality	Type
Eastern region	Shosf	Intermediate type (*b*) predominant.
	Birjand to Gonabad	All the three types almost equally distributed.
Northern & western region	Turbat-i-Haidri to Morchikhat.	Open bolled type (*c*) predominant.
Western region	Anoushirwan to Persepolis.	Intermediate type (*b*) predominant. The cotton of these parts was soft to feel and it was just possible that it might have come from Gonabad *via* Tabbas and Posht-Badam. There was a good deal of traffic on that line (Fig. 1.)

The variation in all plant characters, particularly in hairiness, number, size, shape and opening of the boll, lint characters and ginning percentage was very great in areas ranging from Shosf to Tuss in the east, Ghademgala and Sudkhar to Dameghan in the North and Qom to Bagh-i-Shah in the north-west.

At Dameghan there were types which had all the characters of var. *typicum* but the bolls were ½ in. in size. Their lint characters varied a good deal from long and soft at Dameghan to either short and soft or short and coarse at Meshhad, Tuss and the remaining of the above places.

Another interesting feature was the occurrence of types intermediate between vars. *typicum* and *frutescens*. [Hutchinson and Ghose, 1937]. They were found in considerable numbers in Meshhad and Tuss, but stray plants could be found all over from Zabol (Siestan) in the east to Bagh-Shah in the north-west.

Forms belonging to *G. herbaceum* var. *typicum* and with red pigment all over the plant body (stem, leaves, flowers, bolls) were also observed. There was considerable variation in the distribution of pigment over the leaves. Some times only the leaf lobes or a part of the leaf would be found red and the rest green. They are locally known as *parsiah* or black winged, on account of the deep purple colour which their bracteoles acquire when the boll is mature. Their lint is white and of average quality. They were found in varying proportions from Meshhad to Isfahan as shown below :—

Meshhad to Tehran	Stray plants
Gushk Nasrat to Kashan	2 to 10 per cent
Abbasabad to Isfahan	1 to 10 per cent

Forms belonging to *G. herbaceum* var. *typicum* and having *khaki* lint were found. They also are known as *Mahali* cottons. The only other name given to them is *surkhcha*, i.e.(resembling red). They formed 10 to 20 per cent of the component of cotton crop in Birjand area and 2 to 5 per cent in Kashan and Morchikhat areas. *Khaki* cottons are late to mature as compared to white linted ones. Their lint which is either short and coarse or of average quality is used for making coarse hand-spun cloths or *khaki* curtains. The latter are very popular amongst Iranees. It is said that formerly the *khaki* cottons were cultivated on a larger scale. The demand being now for long-stapled cottons, the cultivation of *khaki* cotton is decreasing every year.

Examination of the material

Single plant selections.—859 plants (778 white and 81 *khaki*) were selected from different localities in Iran, based on earliness, boll size and length and softness of the lint. These were examined for staple length, swollen-hair diameter and ginning percentage. The procedure adopted was as follows :—

Halo length of all 859 plants was measured by Bailey's protractor. (maximum halo length on five seeds per plant).

Plants which had halo lengths of 28 mm. and above were examined for swollen-hair diameter (fineness). Such plants numbered 499 (493 white and 6 *khaki*).

Out of the plants examined for fineness, the following were selected and ginned :—

(*a*) Those which had 0·023 mm. and below swollen-hair diameter.

(*b*) Those which had 33 mm. and above lint length irrespective of their swollen-hair diameter. Such plants numbered 240 (234 white and 6 *khaki*).

TABLE I

Area	Halo length in mm.				Swollen hair diameter (in units of 0·0033 mm.)				Ginning percentage			
	No. of plants examined	Range of halo length	Mean	σ	No. of plants examined	Range of S.H. D. examined	Mean	σ	No. of plants examined	Range of ginning percentage	Mean	σ
Eastern .	White 515 Khaki 55	25-36 20-30	30·3 23·8	1·90 2·49	White 418 Khaki 6	4–10 7	7·4 7·0	0·99 ...	White 222 Khaki 6	19-59 34-39	32·9 ...	5·61 ...
Northern.	White 151	21-31	25·9	1·90	White 24	7–10	8·5	0·66	White 1	40	40·0	...
Western .	White 112 Khaki 26	20-35 15-25	26·1 20·7	2·53 2·58	White 51	7–8	7·6	0·47	White 11	32-43	37·0	3·14

REMARKS.—It will be seen from the table that eastern region has given the best material as far as the fineness of the lint is concerned. In halo-length though the variation is not as great as that in the western region, the mean value is the highest. The western region comes next in the aggregate qualities of the material. The *khaki* cottons from all regions were much inferior to the whites.

In addition to single plant selections, there were 29 bulk samples, nine of which were obtained through His Britannic Majesty's Consuls at Tehran and Meshhad and the remaining 20 through the Agricultural Department, from Isfahan area. They were examined for lint length, feel and ginning percentage. Data for samples received through His Britannic Majesty's Consuls are summarized below :—

Locality	Boll characters	Halo-length mm.	Feel	Ginning percentage
G. herbaceum				
1. Marvasti . .	Partly open	28-30	Soft	33·3
2. Maibad . .	,, ,,	25-29	Soft	36·3
3. Herat . .	,, ,,	25-29	Soft	35·2
4. Ardekan (mostly R plants)	Open	25-27	Coarse	45·4
5. Balk locality .	Open	22-26	Coarse	37·5
6. Unknown Khaki .	Open	20-25	Coarse	40·0
7. Birjand (soft cotton)	Closed and partly open bolls	25-32	Soft	25·0
8. Birjand (coarse cotton)	Open	24-29	Coarse	37·5
9. Meshhad . .	Partly open	25-30	Moderately soft	40·0

The samples obtained through the Agricultural Department, Isfahan, were all short and coarse and were therefore rejected.

The selected material of *herbaceum* cottons has been distributed between Viramgam, Coimbatore and Trinidad.

A comparison of the Iran *herbaceums* with the standard Indian *herbaceums* with regard to season, soil, yield quality etc. can be had from the tabular statement (Appendix II).

Exotic cottons

Egyptian cotton (G. *barbadense*) is extensively cultivated along the coast of Persian Gulf. In the rest of Iran efforts are being made to replace indigenous cottons by types of American cottons and at the time of visit American cottons formed an important component of cotton crop all over Iran. Western Iran was said to be practically all under types of American cottons, while on the route travelled Neishapur and Sabzawar in the north-east, Mazandaran, Tehran and Qom in north and Shiraz in the south were important centres of American cotton cultivation (Fig. 1.) Besides the cotton known in Iran as pure American, Felistani, Prerout, Iraqi and Novortski were cultivated. Felistani, is however, the most prized cotton in Iran. Though late, it is long stapled and soft. It is said to have been introduced about twelve years ago by a certain Mr. Hakeemi who brought seed from Russia and grew it in Felistan (North Iran). According to Dr. Burns [1938] it is a cross between Egyptian and American cottons made by Mr. Hakeemi. Since it did very well there, the Agricultural Department encouraged its cultivation all over Iran.

Types of American cotton

Felistani cotton, as grown on the experimental farm at Karaj (Tehran) differed from a typical *G. hirsutum* in the following characters :—

Leaf deeply constricted at the base, leaf lobes narrowly triangular, bracteoles not closely investing the bud, flower or boll, corolla moderately expanding, bolls tapering and pointed.

In fields, however, there was a great variation in morphological characters, and in Felistan plants were found in considerable numbers which conformed in every detail to *G. hirsutum*. Felistani can be classified into two classes according to size of seed, and three according to colour as shown below :—

1. Small-seeded . . . . a. black seed, no fuzz, tuft at the pointed end, lint short.
2. Big-seeded . . . . b. brown seed, fuzzy, lint long.
   c. green seed, fuzzy lint long.

Prerout is extensively cultivated in Mazandaran area. Plants are sympodial, tall and vigorous up to 8 ft. in height. Morphological characters resemble those of *G. hirsutum*. The Agricultural Officer, Shahi (Mazandaran), said it was a cross between two varieties of *G. hirsutum*. Prerout is an early and high yielding type with moderate lint chararters.

Iraqi and Novortski are being tried at all the experimental stations in Iran. *Iraqi* is medium in time of maturity, sympodial in habit 1 ft. to 6 ft. high, and thick stemmed. It is a typical *G. hirsutum*, and in lint characters is almost as good as Felistani. Novortski is morphologically similar to Iraqi but is short stapled and soft.

The *hirsutums* on the whole showed much less variation in morphological characters than the *herbaceums*, which may be accounted for by the fact that they have been introduced in the course of the last 12 years.

Examination of the material

Single plant selections.—In making field collections it was not possible to identify the variety with any certainty and in the examination of the material, therefore, no account was taken of the name under which the cotton was being grown. 302 of the plants collected on the basis of earliness, boll size, length and feel of lint, were examind for lint length, fineness and ginning percentage in the same way as described for *G. herbaceum*.

TABLE II

Area	Halo length in mm.				Swollen hair diameter (in units of 0·0033 mm.)				Ginning percentage			
	No. of plants examined	Range of halo-length	Mean	σ	No. of plants examined	Range of halo-length	Mean	σ	No. of plants examined	Range of ginning percentage	Mean	σ
Eastern .	131	24–37	29·5	2·99	93	6–9	7·3	0·62	41	30–47	36·0	3·87
Northern .	100	23–36	29·5	3·15	70	7–10	7·8	0·62	19	27–43	33·0	4·31
Western .	71	26–36	29·7	2·24	61	6–8	7·2	0·52	60	15–48	35·0	5·22

REMARKS.—It will be seen from the table that taking into consideration all the three characters, lint length, fineness and ginning percentage, the western region has given the best material and the eastern the second best.

Bulk samples.—These samples where obtained from His Britannic Majesty's Consul at Meshhad and their characters are summarized below :—

Locality	Boll size	Lint length mm.	Feel	Ginning percentage
Meshhad (*G. hirsutum*) .	Moderate	25–30	Soft	36
Meshhad (Felistani) . .	Large	26–31	Soft	23

The selected material of *hirsutums* has been distributed between Coimbatore, Lyallpur and Trinidad.

The lint of both the *herbaceums* and *hirsutums* collected in Iran were sent for fibre test to the Technological Laboratory, Matunga. The fibre particulars received from there are given below :—

	G. hirsutum	*G. herbaceum*
1. Mean fibre length (inch)		
(a) By Balls sorter	1·04	0·90
(b) By Baer sorter	1·08	0·90
2. Mean fibre wt. per inch (one millionth of an ounce) . . .	0·136	0·120

The *hirsutums* according to the report are 18 per cent longer but 13 per cent coarser than the *herbaceums*. The former is rather coarse for its length and has a rough feel while the latter is finer than is usually the case with Indian *herbaceums* and has a slightly silky feel.

SUMMARY

(1) The indigenous cottons, i.e. the *herbaceums*, exhibited great variability in ginning percentage, lint length and fineness. The introduced cottons, i.e. the *hirsutums* were variable in the first two characters only. Variation in morphological characters of the *herbaceums* was considerably greater than that of the *hirsutums*.

(2) The best material of *herbaceums* was obtained from the eastern region good material was also found in western Iran, but that collected in the north

was inferior. Zabol (Siestan area) in the east was also reputed to produce good quality and highly variable material but, due to failure of the crop in 1936 season, enough samples could not be collected to give any detailed information about it.

(3) According to the report received from the Technological Laboratory, Matunga, on the material brought from Iran, the *hirsutums* were 18 per cent longer but 13 per cent coarser than the *herbaceums*. The former was rather coarser for its length and had a rough feel, while the latter was finer than was usually the case with Indian *herbaceums* and had a slightly silky feel.

(4) The *hirsutums* in Iran suffered heavily from pests and diseases, while the *herbaceums* were found to be comparatively free.

(5) The *herbaceums* that were come across were all highly sympodial as would be expected in a country with early frosts and severe winters. To hasten maturity, it is a general practice in Iran to pluck the leaves and top the plants at all stages from the bud to the boll-forming period.

(6) The cotton samples collected have since been grown at Viramgam (Gujrat) and Coimbatore. A part of the material is also being tried by Mr. J. B. Hutchinson at Trinidad.

(7) The analysis of the soil samples showed that excepting the region between Qom and Isfahan, which had heavy soils and was predominantly a *herbaceum* area, the light soils had predominance of the *herbaceum* type and the heavy soils that of the *hirsutums*. Zabol (Siestan) had light sandy loam and though at the time of visit was predominantly under *hisrutums* it was essentially a *herbaceum* area and has been well known for the good qualities of the latter.

(8) The total area under cottons in Iran in 1932-33 was about 1·5 million acres and the produce about 2·9 million bales of 400 lb. each, thus giving an yield of about 700 lb. of *kapas* per acre.

ACKNOWLEDGEMENTS

I am grateful to the Indian Central Cotton Committee, Bombay, and the Director, Institute of Plant Industry, Indore, for deputing me to survey the cotton areas in Iran, and I feel highly indebted to Sir Bryce Burt for very kindly affording me every facility for arranging my tour in that country.

I am highly indebted to Mr T. R. Low and Mr J. B. Hutchinson for their helpful advice and the keen interest they took in the progress of my work in Iran. To Mr Hutchinson's valuable guidance and criticisms in examining the material, I owe the report submitted to the Cotton Committee in February 1937. My thanks are due to Mr K. Ramiah for his help in rewriting the original report in the form of a paper. I am also thankful to Mr O. K. Caroe, then Deputy Secretary, Foreign and Political Department, Government of, India, Mr N. M. Butler, Counsellor, British Legation, Tehran, Major J. Campbell British Vice-Consul, Zahidan and Aqai Adal, Naib Raees-i-Falahat, Tehran, for affording me the facilities required during my tour in Iran.

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Appendix I

Details of area under cultivation and yield of cotton in Iran

Name	Acres	Yield of *kapas* in bales of 400 lb. each
Tehran	25293	45641
Azarbyjan (east)	15931	32478
Azarbyjan (west)	2487	5779
Khorasan	26962	51668
Kerman	5063	4795
Siestan	1235	1632
Faras	820	2583
Khouzistan	291	5959
Khamseh	1111	1959
Qazvin	2766	6474
Hamadan	420	1273
Kirmanshah	252	354
Kurdistan	*	*
Louristan	*	*
Iraq	840	1861
Golpayegan	*	*
Malayer	494	490
Isfahan	11599	18512
Yezd	6879	20705
Kashan	6661	14578
Qom	1265	2922
Semnan	8497	11101
Shahroud	210	637
Dasht-i-Gorgan	743	1485
Gorgan	7632	10105
Mazandaran	22477	44730
Guilan	*	*
Ports of Persian Gulf	25	653
Total	149956	288374

* The statistics for Kurdistan, Louristan, Golpayegan and Guilan were not available.

Appendix II

Comparison of the Iran herbaceums *with standered Indian* herbaceums

Datta for Indian cottons are from *I. C. C. C. Tech. Bull. No. 45, 1938*

Iranian herbaceums

Type	Districts of growth	Growing period	Soil	Annual rainfall	Temperature in °F.	Yield of *Kapas* per acre	Ginning percentage	Fibre length in inches Balls Baer	Fibre wt. per inch in millionth of an ounce
Iranian *herbaceums*	Siestan, Khorasan, Guilan and areas of Qom, Kashan Isfahan and Faras.	Sown all over Iran from March to May except in South Iran where it is earlier, the first 3 weeks of February. Picking from July to October.	Predominate in light loam. The exceptions are the heavy soil areas of Tehran to Morchikhat and of Isfahan.	In Siestan and east Khorasan about 4". In western Khorasan about 9". In Tehran and round about 5 in. In Isfahan about 6 in. and in Bushire—about 13 in. The number of irrigations varies from 4 to 6 depending upon the availability of water.	At Mashhad (Khorasan) mean = 56·3 and range from 15 to 76. At Tehran, mean = 60·4 and range from 30 to 111. At Isfahan mean = 58·0 and range = —3 to 106. At Shiraz, mean = 65·0 and range = 21 to 113. At Bushire average = 91·0 and range = 75 to 109.	400 to 600 lb.	33 per cent in East Iran 40 per cent in Guilan area and 37 per cent in Isfahan area.	0·90, 0·94	0·195
Indian herbaceums									
Jaywant .	Dharwar, Belgaum Bijapur, etc.	Sown from the 1st week of August to the end of September and usually picked from the 2nd week of February up to middle of April.	Deep and medium black soil.	20 in. to 30 in. .	Average minimum about 60.	Normally about 300 lb.	26–29	0·96, 0·94 in 1937-38.	0·195 in 1937-38.
Surat 1027 ALF.	Broach tract	Sown from third week of June and picked from mid March onwards.	Black cotton soil	30 in. to 40 in. .	Mean 85 from April to August Mean 81 from September to November.	424 lb. in 1937-38.	33·3	0·99, 0·97	0·155
Wagad 8 .	North Gujrat, N. W. Kathiawar and Cutch.	Sown in the beginning of July and picked in March.	*Besar* a saltish alluvium	13 in. to 30 in. .	Mean 110 Minimum 52. Lowest monthly average = 58·7 (January).	Average from 1923-38 594·7 lb.	42	0·82, 0·82 in 1937-38.	0·211 in 1937-38.
Hagari .	Parts of Bellary.	Sown from the last week in August to the end of September and picked from about the first week of February to the end of March.	Black cotton soil	Normally 20 in. .	Mean minimum = 65·1 Range 77·8 to 42·2. Mean maximum = 91·4 Range 104·7 to 80·7	Normally 270 lb.	30	0·88, 0·87 in 1937-38.	0·180

MEGASPOROGENESIS AND THE ORIGIN OF TRIPLOIDS IN *SACCHARUM**

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(Received for publication on 21 June 1939)

(With Plates VII-XVI)

I. Introduction

TRIPLOIDY was first discovered in *Oenothera* [Gates, 1908] and since then has been reported in many genera of plants [Darlington, 1937]. Triploids include two groups, the auto-triploids that have three identical genoms, the chromosome complement of which can be represented as of the constitution **AAA**, **BBB** and so on, and the allotriploids that have sets of chromosomes that are not identical and which could be represented as that of the constitution **AAB** or **ABC**.

Triploids in general may originate in three different ways : (1) through an abnormality in somatic mitosis in the haploid generation such as splitting of chromosomes or reunion of daughter nuclei, (2) through failure of reduction at meiosis and consequent fusion of unreduced ($2n$) and reduced (n) gametes and (3) by hybridization between diploids and tetraploids.

One of the features associated with the cytology of reproduction in *Saccharum* is the phenomenon of doubling in the chromosomes of the pistillate parent of interspecific crosses first reported by Bremer [1923] in natural hybrids between *S. officinarum* var. Black Cheribon ($n=40$) and *S. spontaneum* Glagah ($n=56$). The same feature was observed in crosses between *S. officinarum* var. *vellai*, and other varieties of *S. spontaneum* [Dutt and Rao, 1933 ; Janaki Ammal, 1938, 2], and in several intergeneric crosses effected at Coimbatore.

Bremer considers this doubling of the chromosomes in *S. officinarum* parent, a phenomenon characteristic of interspecific hybridization in *Saccharum* the doubling having occurred in the egg cell during fertilization. Triploids have, however, been found to occur among selfed progenies and intraspecific hybrids of *S. spontaneum* [Janaki Ammal, 1936]. This fact and the presence of abnormal binucleate pollen grains occasionally seen in *S. officinarum* lead one to think that the method of doubling may not be quite as simple as Bremer imagined. The present investigation was, therefore, taken up to discover the exact method of chromosome doubling associated with the cytology of reproduction in *Saccharum*.

II. Material and methods

The two species of *Saccharum* selected for investigation were :—

(1) *S. spontaneum* from Dehra Dun ($2n=56$) ;

(2) *S. officinarum* var. *vellai* of Coimbatore ($2n=80$).

*A thesis approved for the Degree of Master of Science by the University of Madras.

Of these, *S. spontaneum* was a variety raised from seeds sent by Mr Holes from Dehra Dun in the year 1912 and since propagated by cuttings or 'setts' at the Imperial Sugarcane Breeding Station, Coimbatore. *S. officinarum* var. *vellai* is a thick cane grown in Coimbatore district. This cane is male-sterile and has been used extensively at the Coimbatore Sugarcane Breeding Station for hybridization with *S. spontaneum*, *Sorghum* and other genera of grasses and it has been the pistillate parent of the first cross made between *S. officinarum* and *S. spontaneum*.

Fixations were done during the months of August-October in the year 1937. Root-tips were fixed at 11 A.M. in Navashin's fixative [McClung, 1937] and in Medium Flemming; and the young spikelets fixed between 8 and 11 A.M. in Navashin's and Bouin's fluid (as modified by Allen) after prefixation in Carnoy's for a minute. Fixations were made at all stages ranging from divisions in pollen-mother-cells to fully formed pollen grains. Preliminary examination of anthers in acetocarmine [Belling, 1926] was resorted to for selecting right stages. For the study of embryo formation in *S. officinarum*, flowers of *vellai* were artificially pollinated by the Coimbatore form of *S. spontaneum* ($2n=64$) under bag. Spikelets of flowers thus pollinated were fixed in acetic alcohol at intervals of two hours during the first day and at intervals ranging from three to four hours, for a week after pollination. The materials were left in the fixing fluid for 24 hours. Root-tips and flower buds were then washed in several changes of tepid water for three to four hours and mature ovules (fixed in acetic alcohol) in 70 per cent alcohol. Callus hairs and glumes were clipped off the spikelets so as to facilitate sectioning. Dehydration and embedding were done according to La Cour's [1937] schedule.

Sections of root-tips were cut 10μ, flower buds 13μ to 15μ and mature ovules 25μ to 30μ thick. Sections of root-tips fixed in Medium Flemming were bleached in a mixture of three parts 70 per cent alcohol and one part 20 volumes hydrogen peroxide. Sections were stained in Haidenhain's iron-alum-haematoxylin with picric acid as destainer and also in Newton's Gentian Violet-iodine.

All drawings were made with a Spencer Abbé Camera Lucida at stage level. An apochromatic objective 100 (N. A. 1. 3) was used with different eye-pieces to give approximate magnifications indicated below the figures.

III. Somatic chromosomes

Fifty-six chromosomes could be counted at the somatic metaphase of *S. spontaneum* Dehra Dun (PlateVII, fig. 1), thus confirming the count made by Janaki Ammal [1936] for this variety of *S. spontaneum*. In root-tip sections of *S. officinarum* var. *vellai*, the chromosome counts showed the somatic number to be 80, characteristic of *S. officinarum* [Bremer, 1923] (Plate VII, fig. 2). The two species studied showed gradations of size in the chromosome complement. Measurements taken from good metaphase plates showed that the average length of the longest chromosomes in *S. spontaneum* was about 2·8μ while that in *S. officinarum* 3·6μ. The long chromosomes of *S. spontaneum* corresponded in length to that of the medium ones in *S. officinarum*. The short chromosomes in the two species showed an average length of 1·6μ and

were almost identical. The chromosomes of *S. spontaneum* fall approximately into three different types, long, medium and short, according to their length, and could be represented as 8L+32M+16S, while in *S. officinarum*, four types could be distinguished. These can approximately be classified into 10L+20M+30m+20S.

Both primary and secondary constrictions were found in the long chromosomes. Trabants have not been observed in the chromosomes of the two species of *Saccharum* investigated.

IV. Observations on divisions in megaspore-mother-cells of *S. spontaneum* and *S. officinarum*

The archesporial cell in *S. spontaneum* is differentiated early from a group of cells at the apex of the floral axis. It is found to be sub-epidermal in origin and covers nearly a third of the nucellar tissue (Plate VII, fig. 3). It is characterized by having larger nucleus and richer cytoplasm in the resting condition, than those in the surrounding cells. This cell functions as the megaspore-mother-cell without any further divisions as observed in other grasses like *Triticum* [Percival, 1921], *Poa* [Anderson, 1927], *Oryza* [Teradu, 1928], *Zea* [Randolph, 1936] and *Euchlaena* [Cooper, 1937]. The nucellar epidermis immediately above the archesporial cell becomes two-cell thick.

As prophase advances in the nuclei of megaspore-mother-cells, the leptotene threads were found to contract, their uneven granular structure becoming increasingly evident. Polarization of the threads were observed in fixed materials examined at this stage, their free ends being directed to one side of the nucleus towards the micropylar end (Plate VII, fig. 4). The association of chromosomes seen at prophase stage was found to be parasynaptic as also observed in pollen-mother-cells of the plant [Janaki Ammal, 1936], a feature that has now been recognized as universal in meiosis [Darlington, 1931]. It is surprising that Santos [1937] finds the telosynaptic type of chromosome association and the presence of a continuous spireme in the pollen-mother-cells of the Philippine variety of *S. spontaneum* he examined! Terminalization of chiasmata was minimum in the long chromosomes and the chiasma behaviour in megaspore-mother-cells was found to approximate very closely that in pollen-mother-cells of the plant [Janaki Ammal, 1936].

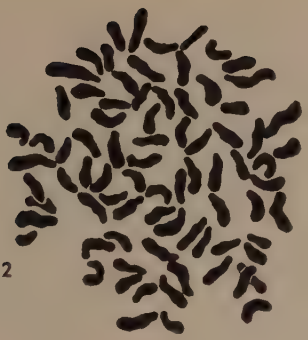
Twenty-eight bivalents could be counted at late diplotene and diakinesis (Plate VII, figs. 5 and 6) each pair being held together by chiasmata. The three types of lengths noticed in somatic chromosomes could be fairly distinguished at meiosis.

In megaspore-mother-cells of *S. officinarum*, 40 bivalents could be counted at diakineses (Plate VII, fig. 7) though occasionally thirty-nine bivalents with one or two univalents were also seen. The bivalents were found paired by chiasmata which varied from one to two in cells examined at diplotene and diakinetic stages. Both terminal and interstitial chiasmata were observed in megaspore-mother-cells. These observations were found to be similar to those on pollen-mother-cells of the same species (Plate VII, fig. 8). A normal bipolar spindle (Plate VII, fig. 9) was observed in both the species. Secondary association of the chromosomes was well marked at the metaphase stage of division. During anaphase stage in megaspore-mother-cells of *S. officinarum*,

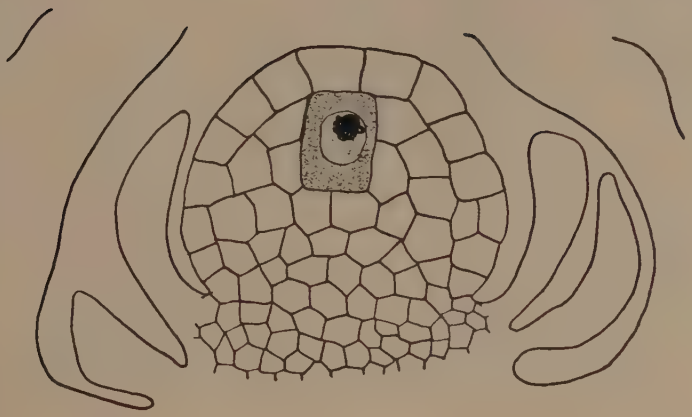
PLATE VII

1 & 2: Mitotic metaphases in root-tip cells of *S. spontaneum* ($2n=56$) and *S. officinarium* ($2n=80$) (magnified); 3: Subepidermal archesporial cell in nucellar tissue (×500); 4: Polarisation at leptotene stage (× 1500); 5: Diakinesis showing 28 bivalents (× 1875); 6: Configuration of bivalents from one megaspore-mother-cell at diakinesis (× 1875); 7: Diakinesis in m.m.c. of *Saccharum officinarum* showing 40 bivalents (× 1875); 8: Diakinesis in p.m.c. of *vellai* (× 1875); 9: First Division Metaphase —side view (× 1500); 10: First Division Anaphase in m.m.c. of *vellai*, showing the univalents separating to the poles (× 1500); 11: Late telophase of first division in m.m.c. of *S. spontaneum* (× 1500); 12: Dyad cells after the first division of megaspore mother-cell (× 1500)

1



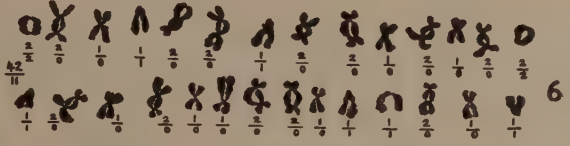
2



3

4

5



6

7

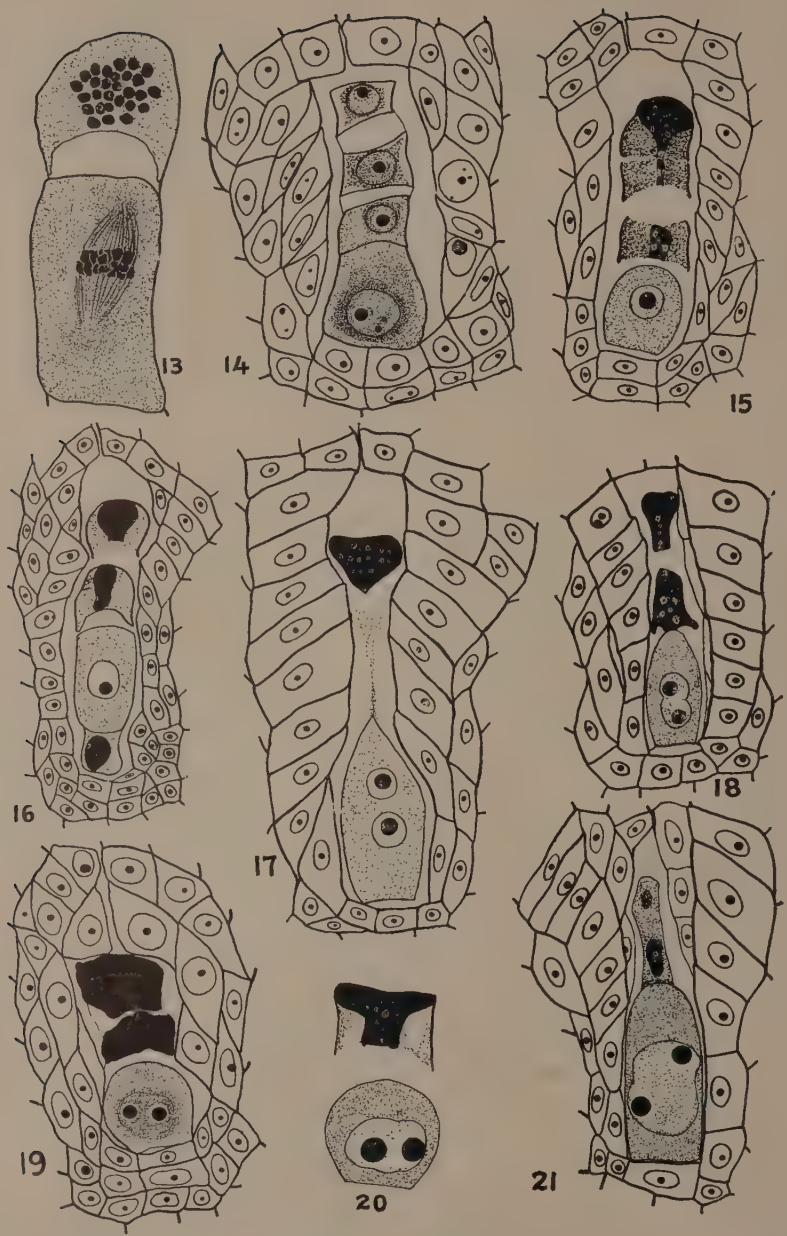
8

9

10

11

12



13: Second division metaphase in dyad cells of *S. spontaneum* (× 1500); 14: A linear tetrad of megaspores formed after the meiotic divisions (× 750); 15. Linear spore-tetrad showing the innermost functional megaspore (× 750); 16: A liner spore-tetrad showing the functional sub-chalazal megaspore (× 750); 17: Binucleate chalazal megaspore (× 750); 18: Fusion of the two megaspore nuclei with the outer two megaspores in a degenerate condition (× 750); 19: Chalazal fusion nucleus (diploid megaspore) in *S. spontaneum* with two degenerated megaspores (× 750); 20: 'Fusion nucleus' in *S. spontaneum* with an outer undivided and degenerated dyad (× 1500); 21: Fusion of two megaspore nuclei in chalazal cell in *S. officinarum* (× 750)

the forty chromosomes were seen separating to the poles and a tendency for one or two univalents to lag was perceptible in certain cells (P ate VII, fig. 10).

The anaphase and telophase stages were normal in both the species of *Saccharum*, and two dyad cells each with the reduced number of chromosomes were formed (Plate VII, figs. 11 and 12). Wall formation was, however, found to be somewhat delayed at the first division in *S. officinarum*.

The second division spindles formed in the two dyad cells in both the species were found to be in the same plane as the first division spindles. The 28 chromosomes were counted at second metaphase in *S. spontaneum* (Plate VIII, fig. 13) and a linear quartet of megaspores was observed at the end of second telophase (Plate VIII, fig. 14). As in other members of the Graminae the innermost of the tetrad was found to be functional, the rest degenerating (Plate VIII, fig. 15). Anderson [1927] finds that the topmost one may develop in *poa*. Occasionally, however, I find the outer of the two inner megaspores (sub-chalazal) to develop in *Saccharum* (Plate VIII, fig. 16).

When a large number of spikelets of both the species were examined at this stage, it was found that occasionally two inner or chalazal megaspore nuclei were enclosed in a common cell. Such binucleate megaspores (Plate VIII, fig. 17) are formed presumably through failure of cell wall formation at the close of the second telophase. They could be distinguished from two-nucleate embryo-sacs by their smaller size, and the presence of the degenerated megaspores at the top. The binucleate condition of the megaspore is also supported by the presence of fusion nuclei (Plate VIII, fig. 18) in preparations of later stages. Such ' fusion nuclei ' each with two nucleoli of equal sizes enclosed in a common nuclear membrane (Plate VIII, figs. 19, 20 and 21) were found in both the species of *Saccharum* examined. The phenomenon of reunion of two megaspore nuclei at the chalazal end, was found to be more common in the variety Vellai of *S. officinarum*, than in *S. spontaneum*.

Irregularities in megaspore-mother-cells responsible for a number of deviations from the normal were also observed during the course of second division in both the species. Plate IX, fig. 22 shows a stage where the chromosomes of the upper dyad were found to be at metaphase, while those in the lower one had reached the poles. The bipolar spindle formed at second metaphase in the micropylar dyad was found to be almost at right angles to the longitudinal axis of the cell as in *Zea* [Cooper, 1937]. This could give rise to a T-shaped spore-tetrad in *S. spontaneum* as in *Triticum* [Watkins, 1925]. The upper of the two dyad cells was found to degenerate before second division (Plate IX, fig. 23) or to divide and give rise to two megaspores, both however degenerating later (Plate IX, fig. 24), or it started division, but degeneration set in before the completion of the process (Plate X, fig. 25). In such cases the inner dyad proceeded with the devlopment of embryo-sac with the haploid number of chromosomes (Scilla type [Schnarf, 1936] and Allium type [Maheshwari, 1937]). At the time when two megaspores have been formed by the division of the chalazal dyad, the nucleus of the upper one was either in a resting condition (Plate IX, fig. 26) or at the metaphase stage (Plate IX, fig. 27). In both the species of *Saccharum*, the cells on either side immediately surrounding the products of meiotic divisions were somewhat elongated suggesting a tracheidal function.

V. Development of embryo-sac

Observations on meiosis in megaspore-mother-cells have shown that the embroyo-sac development in both the species of *Saccharum* may originate in one of three ways :—

1. From one of the tetrad megaspores (normal type).
2. From fusion of two of the spore-tetrad.
3. From a single dyad cell (Scilla type [Schnarf, 1936] and Allium type [Maheshwari, 1937]).

Of these the more common form was the development from haploid megaspores and dyad cells. The stages of development of haploid and diploid megaspores followed the normal course.

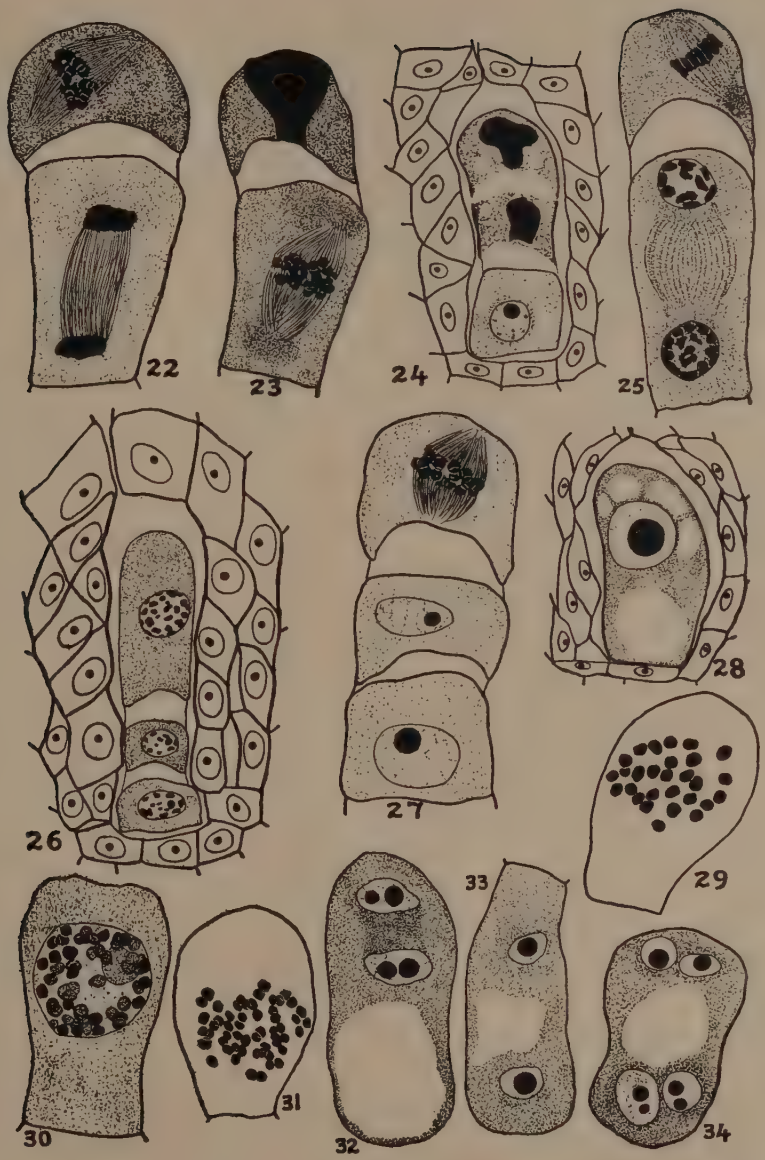
The first sign of embryo-sac formation from a megaspore was the enlargement of the megaspore often accompanied by vacuolization of the cytoplasm, the nucleus being pushed to the upper end (Plate IX, fig. 28). The 28 chromosomes could be counted at metaphase (Plate IX, fig. 29) in a large number of sections examined and the $2n$ number 56 in those arising from diploid megaspores (Plate IX, figs. 30 and 31). Secondary association was marked at this stage also.

The micropylar and chalazal poles of a developing embryo-sac were established by vacuolization at the centre. Considerable growth of the cell was noticed after this stage and could be easily differentiated from the binucleate megaspores. The eight-nucleate stage in the embryo-sac was derived by three normal mitotic divisions as in Plates IX and X, figs. 32-35, the egg-cell with its two synergids and a polar nucleus being differentiated at the micropylar end and the three antipodals at the chalazal end. The two polar nuclei were found to occupy a position just below the egg cell.

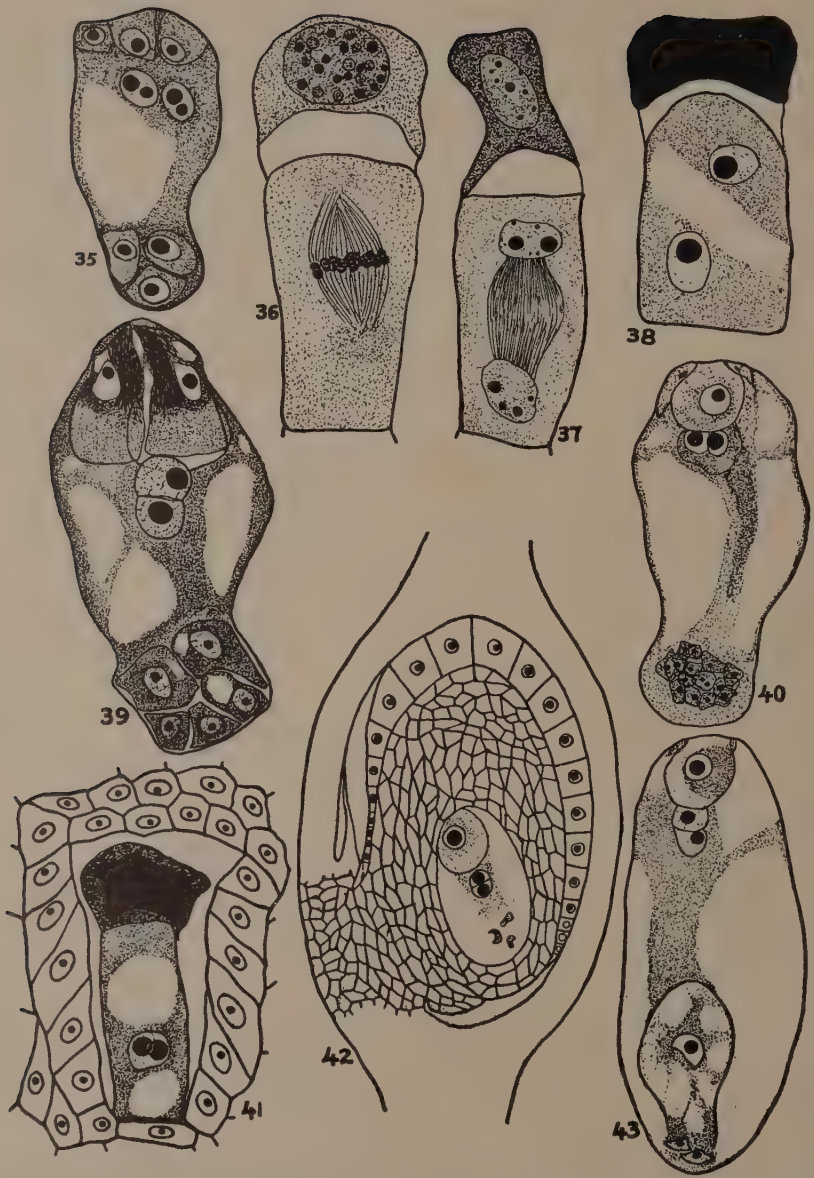
Development from haploid megaspore

The development from the haploid dyad cell as in *Scilla nonscripta* [Hoare, 1933] was found to be similar to that from the megaspore. The degeneration after the first division and before the second division of the micropylar dyad cell was observed and was found to persist as a darkly stained mass over the embryo-sac. In this type of development (Plate X, figs. 36, 37 and 38) the second division of meiosis represents the first mitotic division of embryo-sac formation, and the two processes merge into one another indistinguishably [Chiarugi, 1926 ; Schnarf, 1936 and Maheshwari, 1937]. The same type of development with a reduction in the antipodal cells at the chalazal end of embryo-sacs has been observed in *Alismaceae* [Dahlgren, 1928 ; Johri, 1935, 2, 3, 1936] and in species of *Allium* [Messeri, 1931 ; Jones and Emsweller, 1936].

In the fully-developed female gametophyte, the synergids showed longitudinal striations in the narrower end (Plate X, fig. 39). The synergids possessed also a hook or a beak. An antipodal tissue was derived by further divisions of the primary antipodal cells, as observed in several members of the Graminae like *Triticum* [Watkins, 1925 ; Wakakuwa, 1934-35], *poa* [Anderson, 1937], *Avena* [Kihara and Nishiyama, 1932], *Oryza* [Morinaga and Fukushima, 1934 and 1935], barley [Pope, 1937], *Zea* [Randolph, 1936 ; Cooper, 1937] and *Spartina* [Curtis, 1937]. In *S. spontaneum* this antipodal



22 : Non-identical stages of second division in m.m.c. of *S. spontaneum* (×1500) ; 23 : An outer degenerated dyad with an inner one showing the first mitotic metaphase of embryo-sac formation (×1500) ; 24 : A triad row of 3 megaspores showing the functional inner one (×750) ; 25 : Non-identical stages of second division of meiosis : the upper one shows signs of degeneration (×1500) ; 26 : Triads with two inner megaspores and an upper dyad (×1500) ; 27 : Late division of the upper dyad while the inner one has completed division (×1500) ; 28 : Embryo-sac cell of *S. spontaneum* with the resting nucleus (×750) ; 29 : First somatic metaphase of a haploid embryo-sac-cell of *S. spontaneum* showing the 28 chromosomes (×1500) ; 30 and 31 : Late prophase and metaphase stages of first mitotic division of a diploid megaspore showing 56 chromosomes (×1000) ; 32 and 33 : 2—nucleate embryo-sacs (×750) ; 34 : 4-nucleate embryo-sac. (×750).



35 : A young embryo-sac of *S. spontaneum* (×750) ; 36, 37 and 38 : Development of the chalazal dyad (Allium type) ; 39 : Synergids in a mature embryo-sac of *S. spontaneum* showing the filiform apparatus with a beak or a hook (×750) ; 40 : Embryo-sac of *S. spontaneum* showing antipodal tissue (×300) ; 41 : Fusion of daughter nuclei of the first mitotic division in an embryo-sac cell of *S. spontaneum* (×700) ; 42 : Reversal of embryo-sac in an ovule of *vellai* (×100) ; 43 : Embryo-sac of *vellai* showing an antipodal egg-cell (×250)

tissue was composed of 15 to 20 cells (Plate X, fig. 40). Such an aggressive type of tissue seems to be a primitive feature since reduction in gametophytic tissue is characteristic of the advanced members of angiospermous families.

The development of the female gametophyte in *S. officinarum* from megaspores and dyad cells was similar to that in *S. spontaneum*. The formation of a filiform apparatus associated with the synergids was not, however, characteristic of this species and the three antipodal cells were crescent-shaped in appearance. Each antipodal cell had a single nucleus, unlike that in *Zea* [Cooper, 1937],where two or more nuclei were observed, or in triploid *Oryza* [Morinaga and Fukushima, 1937] where as many as 17 nuclei in each antipodal cell have been reported.

VI. Abnormalities associated with embryo-sac formation in *Saccharum*

The following abnormalities were observed during the course of the investigation :—

1. Fusion of the daughter nuclei.—The two daughter nuclei formed after the first mitotic division in the developing dyad cell instead of separating to the poles, were found to fuse together. Plate X, fig. 41 represents such a fusion nucleus with the micropylar dyad in a degenerate condition. The cell in which a fusion was observed was three to four times as long and broad as the binucleate megaspores and was found to behave as a young embryo-sac. The embryo-sacs developed from such nuclei should all have a diploid chromosomal constitution. Thus a condition for the formation of $2n$ gametes was found in sporogenesis as well as during embryo-sac formation.

2. Reversal of normal embryo-sac.—Reversal of the normal embryo-sac, viz. the egg apparatus occupying the chalazal end and the antipodals the opposite end, was occasionally seen in *S. officinarum* var. *vellai* (Plate X, fig. 42). Such a feature has been reported in embryo-sacs of a cross between *vellai*×C A C 87 by Dutt and Rao [1933].

3. Secondary egg cells in embryo-sac.—Several abnormalities associated with the antipodal cells were observed. Occasionally one of the antipodal cells at the chalazal end of embryo-sacs of *S. officinarum* simulated an egg cell, the other two apparently forming the synergids (Plate X, fig. 43). The normal egg apparatus was also present at the micropylar end. Such duplicated egg cells in an embryo-sac would probably give rise to double embryos. Similar egg-like antipodal cells have been reported in *Allium nigrum* [Modilewski, 1931] and *Allium subhirsutum* [Messeri 1931]. The presence, at the micropylar end in embryo-sacs of *S. officinarum*, of an additional egg-cell with two polar nuclei, but with no trace of antipodals at the chalazal end, shows that they are transformed antipodal cells (Plate XI, fig. 44). Plate XI, fig. 45, shows a similar feature in *S. spontaneum* but as the three antipodals are also observed, twin egg cells in this case are probably derived by extra divisions of the nuclei, after the third mitosis of embryo-sac formation.

4. Binucleated antipodal egg.—An antipodal egg-cell in which two nuclei, probably derived by fusion of two antipodal cells, were found closely adhering to each other for fusion. In such cells one of the antipodals was found to simulate a synergid. The normal egg-apparatus at the micropylar end was then found to be in a degenerate condition (Plate XI, fig. 46).

5. Abnormal divisions of antipodal cells.—Unlike *S. spontaneum*, the three antipodals in *S. officinarum* rarely divide to form a tissue. However, the propensity for activity was evident in several ways. The three primary antipodal nuclei fused together and presented a swollen appearance (Plate XI, fig. 47) or the nucleus in each antipodal cell gave rise to several free nuclei without cell-wall formation (Plate XI, fig. 48). Plate XI, fig. 50 shows that two of the antipodal cells are enlarged, the third one by further divisions is seen to simulate an embryo. Later stages of these have, however, not been observed.

6. Secondary embryo-sacs.—Two embryo-sacs are sometimes observed embedded in the same nucellar tissue (Plate XI, fig. 50), as reported in *poa* [Anderson, 1927]. These probably arise from two functional megaspores. Seeds derived from such ovules would show twin seedlings on germination.

7. Parthenogenetic development of egg cell.—In sections of an unpollinated ovule of *S. officinarum* an embryo was found to have developed at the micropylar end (Plate XI, fig. 51). The two polar nuclei were still unfused and showed signs of disintegration.

8. Nucellar embryony.—Plate XI, fig. 52 shows a four to six-celled embryo formed by one of the cells of the nucellar tissue, in an ovule just at the time of pollination. It is highly probable that this embryo is formed apogamously.

Plate XII shows a schematic representation of stages in divisions of megaspore-mother-cells and features in embryo-sac formation.

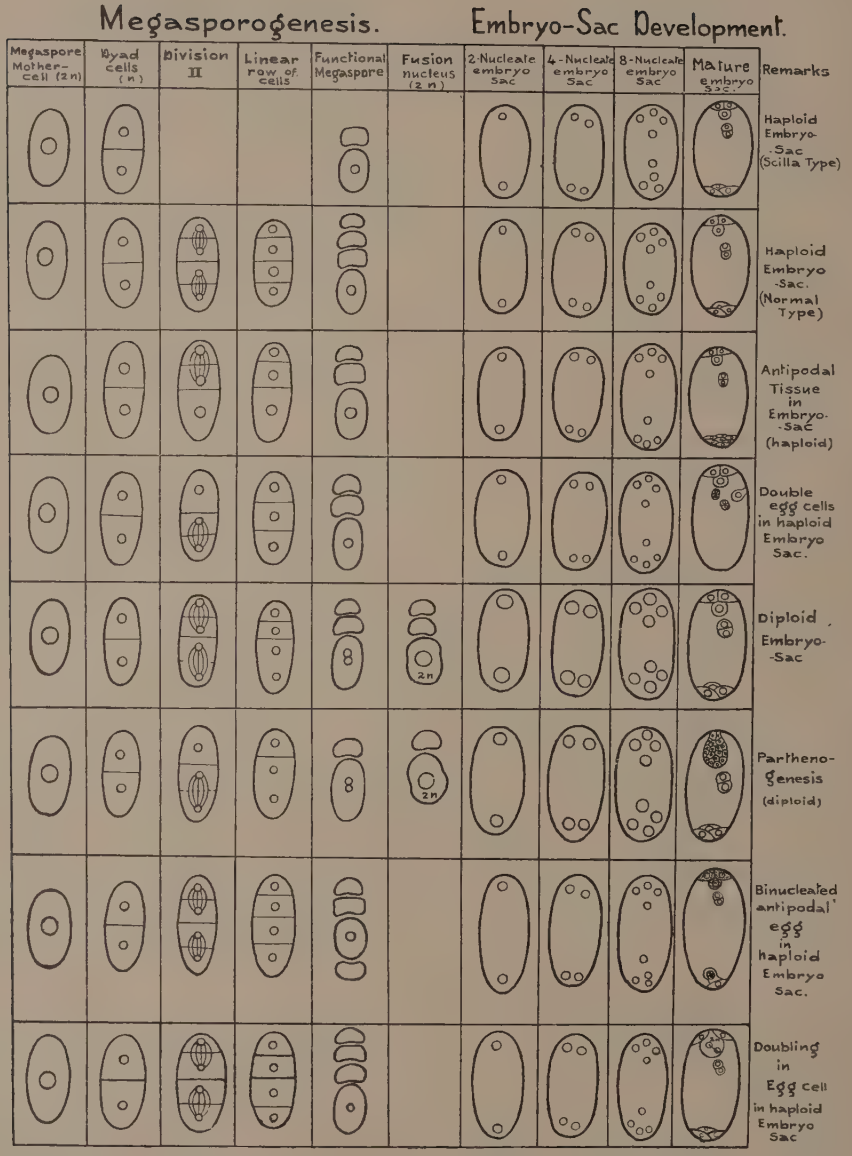
VII. Fertilization and embryogeny in *S. officinarum* pollinated by *S. spontaneum* ($2^N=64$)

In ovules of *S. officinarum*, fixed just before pollination, the normal egg-cell was found to be pear-shaped, with the narrower end towards the micropyle (Plate XIII, fig. 53). The two polar nuclei were found in close proximity to the egg cell and were surrounded by rich cytoplasm. In one instance, the egg cell and synergids were found to be connected together by a peg-like growth from the latter which showed signs of degeneration. This phenomenon seems to indicate that the synergids function as suppliers of nutrients to the developing egg cell. The three antipodals were either prominent or showed signs of degeneration.

In materials fixed two hours after pollination with *S. spontaneum*, no apparent changes were observed in the embryo-sac. The volume of the egg cell, however, was found to have considerably increased in ovules fixed four hours after pollination. Starch grains and oil globules had formed around the egg nucleus. Six hours after dusting with pollen, pollen tubes were found growing between the integument and the pericarp (Plate XIII, fig. 54). Plate XIII, fig. 55 represents the section of an ovule at the same stage, in which the swollen tip of the pollen tube could be seen to have penetrated the embryo-sac with its two generative nuclei.

In a few of the sections examined, the cytoplasm in egg cell was found to be very granular forming a dense ring of chromatic substances round the egg-nucleus (Plate XIII, fig. 55). Similar chromatic bodies have been observed in *Triticum* by Watkins [1925] and *Eleusine* by Krishnaswami and Ayyangar

44 : Double egg cells at the micropylar end of an embryo-sac of *vellai* with 2 pairs of polar nuclei (×250) ; 45 : Embryo-sac of *S. spontaneum* showing the two egg cells of the micropylar end each with a separate pair of polar nuclei (×250) ; 46 : Binucleate antipodal egg in an embryo-sac of *vellai* with the normal egg apparatus in a degenerated condition (×250) ; 47, 48 and 49 : Abnormal antipodal cells (×250) ; 50 : Secondary embryo-sac in nucellar tissue in an ovule of *vellai* (×250) ; 51 : Nucellar embryo in an ovule of *vellai* (×100) ; 52 : Parthenogenetic development of an egg in *vellai* with the unfused polar nuclei showing signs of degeneration.



Course of megasporogenesis and embryo-sac development in *Saccharum*

[1937]. According to Watkins this ring may be the product of a synergid attacked by the entry of the pollen tube, or coagulation products of the cytoplasmic strands round the egg nucleus. Since degeneration of the synergids before fertilization is a feature commonly observed in this variety of *S. officinarum*, the latter explanation seems to be more likely. Plate XIII, fig. 56 shows the egg cell in the metaphase stage of division in an ovule in which the pollen tube has not penetrated the micropylar end. The two polar nuclei lay close to the egg cell.

Fertilization was found to take place about eight hours after pollination. Plate XIV, fig. 58 shows this condition of the ovule in which one of the male nuclei is found to fertilize the egg and the other one, the polar nuclei. As in other grasses, ferilization of the egg and polars was found to be simultaneous. Plate XIV, fig. 59 shows a united reticulated condition of the chromatic matter in the zygote. The zygote next undergoes a period of rest in which condition it had two nucleoli, one of which was smaller than the other (Plate XIII, fig. 57). These probably belong to the genom of the two parent *Saccharum* species.

The fusion of the two polar nuclei is found to precede their fertilization by the second male gamete as in *Triticum* [Watkins, 1925]. In *Zea*, however, it has been found that the male nucleus and one polar nucleus complete their fusion before they unite [Rhoades —quoted by Sharp, 1934]. The primary endosperm nucleus divides immediately after fertilization and at the first mitotic metaphase the chromosomes were found to approximate in number to 112 of which the haploid set of thirty-two is derived from the male parent.

The plane of the first division of the endosperm nucleus was in most cases almost parallel to the longitudinal axis of the embryo-sac. In sections of ovules examined 22 hours after pollination, a layer of free nuclear endosperm with four to eight nuclei was found to have surrounded the zygote. Later these were found to divide and a feature of the endosperm nuclei was that they showed in several cases identical mitotic stages (Plate XIV, fig. 65). Chromosome counts in good metaphase plates showed the triploid ($3n$) and the pentaploid ($5n$) nature of the endosperm nuclei in different embryo-sacs. Plate XIV, fig. 66 shows the metaphase plate of an endosperm nucleus in which more than 145 chromosomes could be counted. This probably represents a $5n$ endorsperm.

The first division of the zygote was found to occur in ovules fixed 32 hours after pollination (Plate XIV, fig. 60). In *Zea*, Randolph finds this to take place 30 hours after pollination, while in *Hordeum*, Pope [1937] finds the same condition 14 to 15 hours after. In *Avena* crosses, Kihara and Nishiyama [1932-33] report two to four celled stages of embryo, 24 hours after pollination. The division of the zygote nucleus in *Saccharum* was always transverse to the longitudinal axis of the embryo-sac resulting in a two-celled embryo (Plate XIV, fig. 61).

The epibasal cell formed a suspensor of four to five cells (Plate XIV, fig. 69), and the basal cell was divided into two by a longitudinal or oblique cell plate (Plate XIV, figs. 62 to 64). By further cell divisions the pro-embryo assumed a globular shape (Plate XIV, fig. 67), a cross-section of which is shown in Plate XIV, fig. 68 from sections cut at this stage. The developing embryo

was found to be surrounded on all sides by free nuclear endorsperm which became cellular in later stages of development.

The rest of the development of the embryo in *Saccharum* was also found to be similar to that in other grasses. Observations on sections of ovules showed a marked difference in size between the embryos at the four-celled stages. A regularity in the sequence of divisions in the pro-embryo was also noted especially in the small-sized ones. The axis of development of the young embryo was found to be indicated by a central patch of cells that show bigger nuclei with richer cytoplasm than those in the surrounding cells (Plate XIV, fig. 70). Disorganisation of the antipodal cells was found to take place simulatenously with the formation of endosperm [Artschwager *et al.*, 1929]. The antipodal tissue in *Zea* and *Coix* occasionally retains its activity even up to the time the seed is mature [Weatherwax, 1930 ; Randoplh, 1936] while in *Poa*, the antipodals persist till late in the endosperm formation and then degenerate.

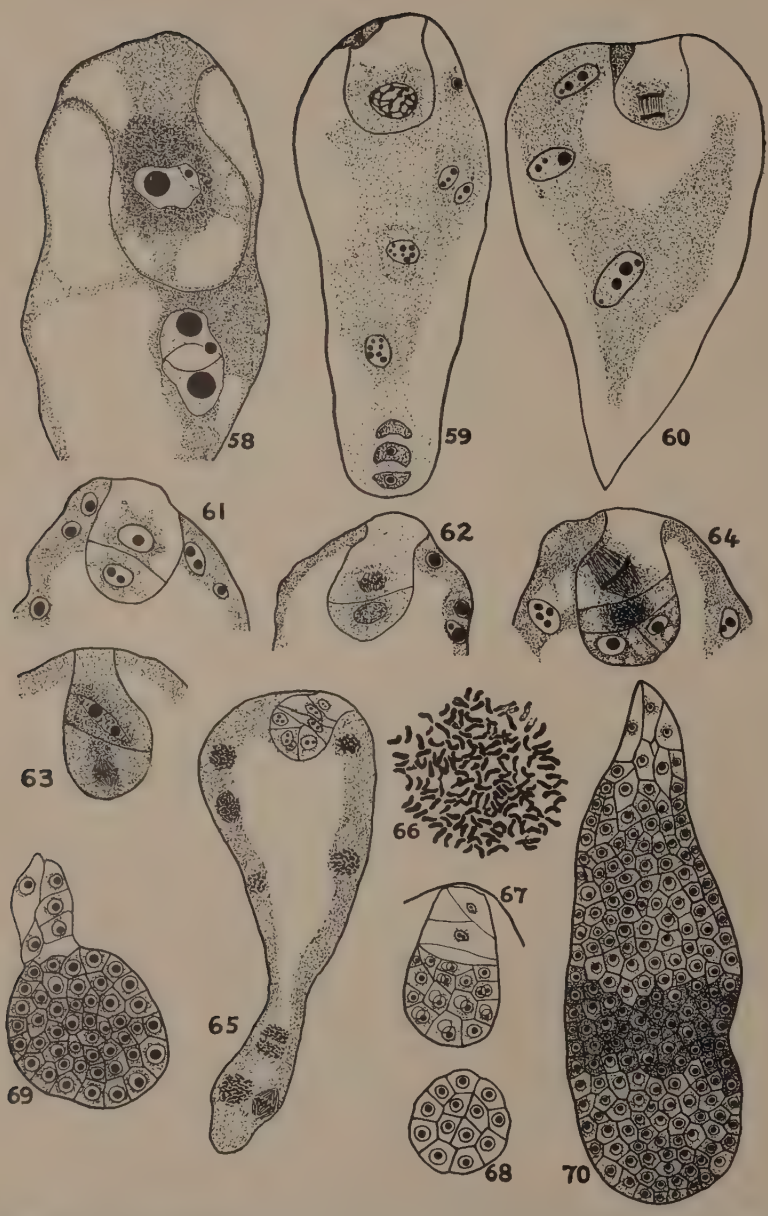
VIII. Discussion

(*a*) *Production of triploids and the condition of polyploids in* Saccharum

The most widely prevalent method of triploid formation in flowering plants has been traced to the union of gametes that have a diploid and haploid chromosomal constitution. Direct cytological evidence for the origin of a triploid through an unreduced female gamete being effective in fertilization, has, as Sansome and Philp [1932] have observed, been rather meagre in most cases. More often the evidences for such are based on genetical studies Triploid progenies through fusion of n and $2n$ gametes (arising presumably through irregularities in meiosis) have been reported in a large number of plants as in *Crepis* [Navashin, 1929], *Nicotiana* [Brieger, 1928], *Rosa* [Erlanson, 1929, 1933 and 1934], *Galeopsis* [Müntzing, 1930], *Musa* [Cheesman, 1931], *Gossypium* [Skovsted, 1934], *Veronica* [Graze, 1935], *Delphinium* [Lawrence, 1936], *Vitis* [Olmo, 1937], *Lolium* [Jenkins and Thomas, 1938], etc. Back-crossing the F_1 progenies with one of the parents has resulted in the production of triploid plants in *Raphano-Brassica* [Karpechenko, 1927] and *Nicotiana* [Lammerts, 1929]. Allo-triploids have also been obtained in intergeneric crosses between *Zea*, *Tripsacum* and *Euchlaena* [Manglesdorf and Reeves, 1935]. A triploid radish × turnip hybrid has risen through functioning of diploid radish egg cell [Morris and Riccharia, 1937].

In most of the plants in which triploidy has been observed, the plants are either diploids or lower polyploids. *S. officinarum*, with $2n=80$ chromosomes, represents an octoploid with a basic number ten, while *S. spontaneum* ($2n=56$) has been considered to be a dibasic octoploid [Janaki Ammal, 1939]. My observations show that triploids are produced in *Saccharum* through a diploid egg cell being effective in fertilization. Such triploids differ from the normal ones in that their haploid number of chromosomes already represent a high ploy ploid condition. They are, therefore, ' triplo-polyploids ' [Janaki Ammal, 1939] and similar to the mutant triploids occurring in secondary polyploids like *Pyrus* [Darlington and Moffett, 1930 ; Hailborn, 1935].

53: Mature embryo-sac of *vellai*: a peg-like growth from the synergids is seen to connect the egg cell (×400); 54: Shows pollen tubes growing between the integument and pericarp: one is seen to have penetrated the micropyle with its two generative nuclei (× 100); 55: Embryo-sac showing dark bodies deposited round the egg nucleus during the entry of pollen tube (× 250); 56: Embryo-sac of *vellai* showing the egg nucleus at metaphase stage of division before the penetration of pollen tube (× 250); 57: Zygote showing 2 nucleoli of different sizes and surrounded by free nuclear endosperm (× 250)



58: Fertilisation of the egg and polar nuclei (× 400); 59: Embryo-sac showing zygote nucleus in a united reticulated condition (× 250); 60: Anaphase of first division of zygote nucleus (× 200); 61: Two-celled embryo (× 375); 62, 63, 64: Show the development of the embryo (× 375); 65: An embryo surrounded by free-nuclear endosperm in identical mitotic stages of division (× 300); 66: Metaphase plate of an endosperm nucleus showing 144 chromosomes (× 1500); 67: An embryo globular in shape (× 250); 68: Cross section of an embryo at the stage shown in Fig. 64 (× 250); 69: Globular embryo with a suspensor of 4—5 cells (× 200); 70: A mature embryo showing differentiation of a central patch of cells marking off the axis of further development (× 200)

Cytological studies by Bremer in the hybrid '*Kassoer*', obtained from crosses between *S. officinarum* var. Black Cheribon ($2n=80$) and the wild *Glagah* (*S. spontaneum*) at Java ($2n=56$), revealed that 68 bivalents are formed at diakinesis and metaphase stages of first division in pollen-mother-cells. The plant showed 136 chromosomes in somatic cells instead of the expected number 96. This duplication of the monoploid set of chromosomes occurred in *S. officinarum*, the pistillate parent. In none of his preparations of *S. officinarum* at reduction divisions in megaspore-mother-cells, was he able to find a single instance of non-reduction. This led Bremer [1923, 1929] to conclude that the phenomenon of doubling of chromosomes in the female, is characteristic of species hybridization in *Saccharum*, doubling taking place 'by a longitudinal splitting of chromosomes in egg cell, the chromosomes of *S. spontaneum* remaining unsplit'. The production of autotriploids among selfed seedlings and triploid hybrids among interaspecific crosses between different chromosomal types of *S. spontaneum* [Janaki Ammal, 1938, 2] show that causes other than species hybridization are responsible for the origin of triploids in this genera of grasses.

(*b*) *Formation of* 2n *gametes in* Saccharum

Various irregularities during meiosis or in premeiotic divisions in archesporial cells have been found to lead to non-reduction and development of unreduced gametes. Thus retardation or suppression of first division has been observed in *Papaver* [Ljungdahl, 1922] and *Taraxacum* [Gustaffson, 1935], and nullification of first or second division has been found in plants like *Prunus* [Darlington, 1930], and *Hieracium* [Rosenberg, 1927]. Double division of univalents, associated with complete failure of pairing at metaphase found in moth hybrids [Federley, 1931], have not been commonly observed in flowering plants, though found to occur sporadically in *Ribes* [Meurman, 1928]. Ramanujam [1937], however, reports such a feature to occur in pollen-mother-cells of F_1 hybrids of *Oryza*. Syndiploidy as found in anthers of *Ochna* [Chiarugi, 1930], *Lactuca* [Gates and Rees, 1921], *Triticum* [Gaines and Aase, 1926], *Zea* [McClintock, 1929], *Avena* [Nishiyama, 1931; Ellison, 1937] and *Chrysanthemum* [Shimotomai, 1931] have not been observed in archesporial cells in ovules.

Though similar abnormalities were expected in megaspore-mother-cells of *Saccharum*, my observations have shown that normal reduction division occurs in both the species giving rise to a spore-tetrad or a triad row of three cells, viz. an undivided dyad and two megaspores. A reunion of two megaspores that have each a haploid set of chromosomes leads to the formation and development of diploid megaspores in both the species of *Saccharum*. That the two nuclei fuse together is evident by the presence of 'fusion nuclei' found to be formed in a common cell at the pollen grain stage in anthers. A similar reunion of daughter nuclei was also observed after the first mitosis of embryo-sac formation from a haploid dyad cell, a feature interpolated in the course of a Scilla type of development. Such 'fusion nuclei' are found to give rise to diploid embryo-sacs, as the duplicated number of chromosomes could be counted at the first somatic metaphase of embryo-sac formation.

The occurrence of triploid ($3n$) and pentaploid ($5n$) endosperm show that normal and diploid female gametophytes are effective in fertilization in both the species of *Saccharum*. It follows, therefore, that triploid embryos are produced by fertilization of the diploid eggs, and have resulted in the production of autotriploids in *S. spontaneum* and hybrid triploids in *S. officinarum* pollinated with *S. spontaneum*. It is highly probable that the larger embryos represent such triploid ones.

Reunion of daughter nuclei in the haploid generation has also been observed in *Saccharum*, at the chalazal end in embryo-sacs, giving rise to diploid cells simulating eggs. Such diploid egg cells on fertilization could also give rise to triploid embryos. They might also develop parthenogenetically.

Division of the mature egg at the time of fertilization was observed only in a single instance. This probably represents a doubling of chromosomes presumed by Bremer [1923]. According to him such a splitting of chromosomes is a result of the stimulus of fertilization Midusima and Saito [1937] give the same explanation for the origin of triploid *Brassica-Raphanus* hybrids. Newton [1927] observed a doubling of chromosomes at the chalazal end in the second division of meiosis, in embryo-sacs of the Leiostemones section of *Tulipas*. On two occasions, in *T. Kolpakowskiana*, he also observed its occurrence at the micropylar end. Such a doubling was remarkable in every fertilized ovule in the capsule and the frequent production of autotriploids among *Tulipas* have been explained in this manner [Darlington, 1937].

However, my observations on the species of *Saccharum officinarum* and *S. spontaneum* show that doubling of chromosomes takes place more often during gametogenesis than fertilization. This feature does not conform to any of the hitherto described types of meiotic irregularities leading to non-reduction, unless we consider this fusion of an already divided dyad as equivalent to ' the nullification of second division '. My observations also show that the same causes that produced autotriplody in *S. spontaneum* are found to be responsible for the origin of interspecific triploids between *S. officinarum* and *S. spontaneum*.

(c) *Time relationships in meiosis*

Non-simultaneous divisions in dyad cells of pollen-mother cells have been reported in a number of grasses like *Eleusine, Oryza*, etc. Observations on divisions in megaspore-mother-cells in *Saccharum* show that nuclear and cell divisions in the inner or chalazal dyad always precede division in the outer or micropylar dyad cell. This delaying of cell division in the upper one has also been found to result in its complete degeneration. Immediately after the first division, the lower dyad is found to increase in length by further growth, whereas the upper one remained without any change. The second divison spindle in the upper dyad was also found to be defective in certain cases. In *Saccharum*, therefore, could be observed an irregularity due to timing and spacial adjustment, brought about by a lack of coordination of certain external and internal agents of cell division. Such a condition may be the outcome of a nutritional advantage of the innermost megaspores of a

linear tetrad, being in immediate contact with the floral axis. This condition does not arise in pollen-mother-cells.

(*d*) *Parthenogenesis in* Saccharum

It has been found that ordinarily the egg cell in normal embryo-sacs develops into an embryo only after fertilization. Several plants have, however, been known to develop haploid embryos by influence of certain external stimuli like electrical, chemical and mechanical injuries inducing the unfertilized egg to develop. Haploids have been produced by selfing in *Nicotiana* [Webber, 1933; Goodspeed and Avery, 1930], and *Solanum* [Humphrey, 1934] or pollination with a different species as in *Datura* [Belling and Blakeslee, 1927] and *Solanum* [Jorgensen, 1928]. Heat treatment as in *Zea* [Randolph, 1932] or dusting with X-rayed pollen as in *Triticum* [Kihara and Katayama, 1932; Katayama, 1935, and Chizaki, 1934] have also been found to induce parthenogenesis. In plants like *Allium odorum* [Modilewski, 1930] and certain species and biotypes of *Potentilla* [Müntzing, 1928], parthenogenesis has been induced by pseudogamy, viz. the male gamete merely exciting the development of the egg and then degenerating.

Gaines and Aase [1926] found that haploid *Triticum compactum* arose parthenogenetically following the fusion of both the male gametes with the polar nuclei. According to Haberlandt [1921] the stimulus of degeneration of synergids and nucellar tissue has induced parthenogenesis in *Taraxacum* and *Hieracium*. It has been found that diploid parthenogenesis in species of *Chondrilla* [Poddubnaja-Arnoldi, 1933] and *Taraxacum* [Gustaffson, 1934] has been associated with meiotic irregularities like the formation of restitution nuclei leading to non-reduction and development of unreduced gametes. In *Artemisia nitida* [Chiarugi, 1926], such diploid embryos are produced parthenogenetically in gametophytes developed from a single diploid megaspore as in *Hieracium* and *Antennaria* [Bergman, 1935], and *Poa serotina* [Kiellander, 1935], from one of the diploid dyads as in *Taraxacum* or from one of the tetrad diploid megaspores (*Alchemilla* type).

Since in *S. officinarum*, embryo can develop in unpollinated ovules, the reunion of two megaspores after a normal reduction has to be considered in the light of a 'fertilization'. It is, therefore, in result identical with the sexual fusion of gametes. This fused nucleus (with the constitution of a zygote) develops into a diploid gametophyte, in which one of the nuclei divides to form an embryo at the micropylar end.

The degeneration of the two polar nuclei associated with parthenogenesis is a noteworthy feature in *S. officinarum*. In species such as *Erigeron annus* [Holmgren, 1919], the two may fuse or, as in *Balanophora* [Ernst, 1914], may not fuse. In *Zephyranthus* [Pace, 1913], however, an endosperm tissue was formed by fusion of both the polar nuclei with a generative nucleus.

Nucellar embryony, viz. one of the cells of the nucellus directly developing into an embryo, was found in unpollinated ovules of *S. officinarum*. A similar feature by stimulation of pollination has been observed in *Allium odorum* [Haberlandt, 1923], and in *Zygopetalum Mackayi* [Suessenguth, 1923]. Mangelsdorf and Reeves [1931] observed many parthenocarpic ovaries in *Zea* (♀) × *Tripsacum* (♂) in which the nucellar cells were growing.

In parthenogenetic development in *S. officinarum*, the two polar nuclei which are found in a degenerate condition probably supply the egg with nutrients. In *Crinum* [Tomita, 1931], it has been found that embryo develops without endorsperm formation. Such embryos probably derive nutrients by destroying and absorbing the contents of nucellar cells. Thus failure of endosperm formation that would nourish the embryo seems to be made good by the egg cells deriving food materials from synergids, polar nuclei, antipodal cells and surrounding nucellar tissue.

(*e*) *Polyembryony*

Multiple embryos have been known to develop from cells of nucellus, synergids, antipodal cells, suspensor cells and cells of the integument. This polyembryony has been reported in grasses like wheat, oats and rye [Hansen, 1920—1921], rice [Komuro, 1922 ; Rodrigo, 1925 ; Jones, 1928]. In ovules of *S. officinarum*, double egg cells in embryo-sacs and secondary embryo-sacs as in *Poa*, *Oryza*, etc. developed from more than one megaspore-mother-cell have been observed. These provide the conditions for the production of twin seedlings. Twin seedlings of *Triticum*, *Secale*, *Avena*, *Phleum*, *Poa*, *Festuca*, etc. have shown deviating chromosome numbers one of the twins generally showing to be a triploid [Müntzing, 1937]. It is possible that such seedlings in *Saccharum* would show their normal and polyploid nature as observed in wheat by Namikawa and Kawakami [1934].

(*f*) *Zygotic viability and incompatibility*

Thompson [1930], Weatherwax [1930], Kihara and Nishiyama [1931], Watkins [1932] and Müntzing [1933] are of opinion that there exists a relationship between three mutually dependant and genetically dissimilar tissues in a developing ovule, viz. : (*a*) the maternal tissue or nucellus and integuments, (*b*) the filial sporophyte—the embryo, and (*c*) the endosperm. The numerical relationship between the mother, endosperm and embryo in a normal diploid plant is as 2 : 3 : 2, or in other words, the diploid embryos are in contact with triploid endosperm amidst diploid soma or maternal tissue ; hence the tissues are in equilibrium and give viable seeds. According to them, a lack of harmony in the physiology of the embryo and pistillate plant, as a result of quantitative change alone, would result in a retarded growth of embryo and do not form viable seeds. In a diploid embryo-sac, all the eight nuclei have the same relative constitution as in a normal haploid one. The 3*n* embryo developed on fertilization of diploid egg is in contact with 5*n* endosperm and is nourished by the 2*n* sporophyte. This ratio does not seem to interfere with the viability of the developing embryo, since the competing system forms '*cine vitele Konstallation*' as observed by Müntzing [1930-31].

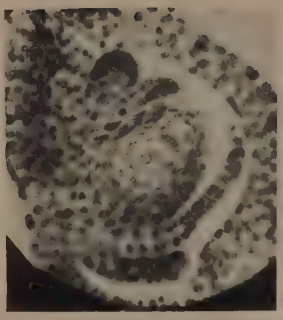
If doubling of chromosomes were to occur in haploid egg cell of *S. officinarum*, it does not lead to a regular chromosomal balance between the different tissue systems, as the triploid embryo resulting from fertilization would be in contact with a 3*n* endosperm. This may probably account for the presence of degenerated embryos observed in a considerable number of ovules and for the high mortality of embryos generally observed in sugarcane as reported by Artschwager *et al.* [1929].

Plate XV

(Microphotographs taken at a magnification (×266) and 5" extension of bellows)

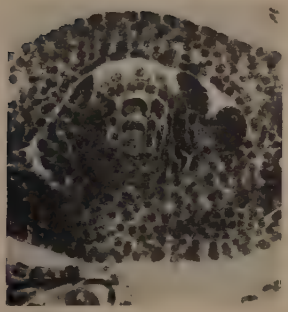
(*a*) Diakinesis in m.m.c. of *S. spontaneum*; (*b*) Dyad cells formed after first division of meiosis; (*c*) Non-identical stages of second division; (*d*) Triads; (*e*) Second metaphase in inner dyad cell with the upper one in a degenerate condition; (*f*) Linear spore-tetrad showing the functional chalazal megaspore; (*g*) Binucleate megaspore with two outer degenerate ones; (*h*) Two-nucleate embryo-sac; (*i*) Mature embryo-sac at the time of fertilization: a connection between egg-cell and synergids by a peg-like growth is seen; (*j*) Parthenogenetic development of egg in *vellai*; (*k*) Metaphase stage of division of egg cell before fertilization: the two polar nuclei are seen in tact; (*l*) Binucleate antipodal egg in an embroy-sac of Vellai.

a

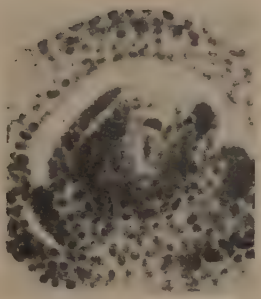


b

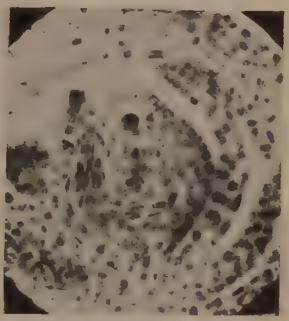
c



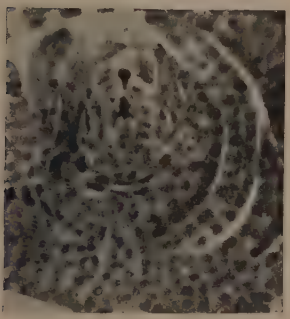
d



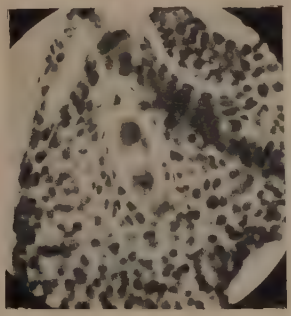
e



f

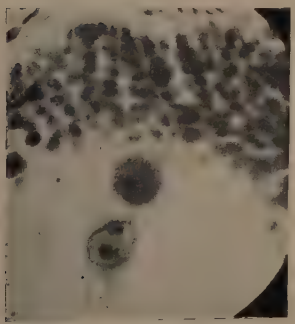


g



h

i



j

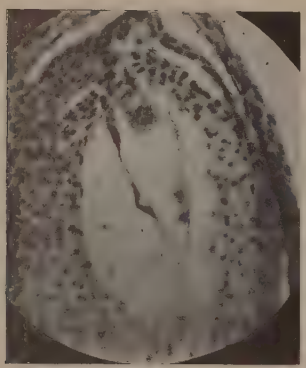
k

l

a

b

c



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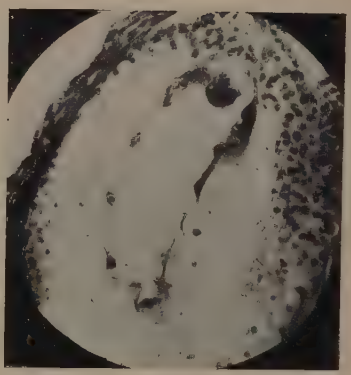

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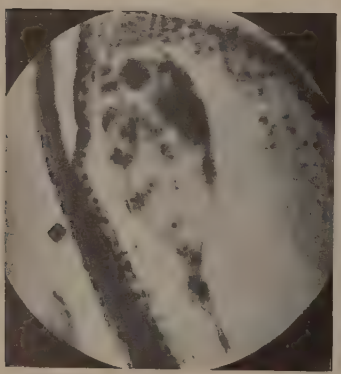

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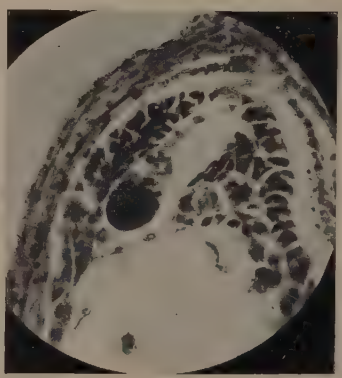

g

(*a*) Mature embryo-sac showing a pollen tube that has come up to the level of the egg cell ; a ring of chromatic bodies are seen round egg nucleus ; (*b*) Anaphase of first division of zygote ; (c) Simultaneous division of zygote and primary endosperm nucleus ; (*d*) Zygote surrounded by a layer of free-nuclear endosperm ; (*e*) Developing embryo surrounded by a layer of free-nuclear endosperm ; (*f*) Embryo enclosed in free-nuclear endosperm ; (*g*) Embryo with a long suspensor.

In crosses between *S. officinarum* and *S. spontaneum* the seedlings obtained have invariably shown a doubling of chromosomes of the pistillate parent. This might be due to a difference in the relative vitality of the uniting haploid gametes to form viable embryos or to some influence external to itself which cause the death of embryo during development of caryopsis. Perhaps the incompatibility of the haploid '*spontaneum*' genom to exist together with the haploid genom of '*officinarum*' to form a viable zygote might be the cause. How far selective fertilization is responsible for the same or whether successful fertilization is the result of a doubling of chromosomes, is hard to say.

In crosses between the noble cane × *Sorghum*, viable embryos are formed from fertilization of both haploid and diploid eggs in the pistillate parent, whereas in *Saccharum* × *Imperata*, only diploid fertilized eggs were found to be viable, unlike that in *Saccharum* × *Bambusa* hybrids [Janaki Ammal, 1938] where only haploid fertilized eggs have been known to be viable. Hence diploid eggs in the noble cane seem to be favoured at the expense of reduced ones in crosses with other species and genera. Seed development, in general, has been found to be better in interspecific crosses, when the parent containing the high chromosome number is the female [East, 1935: Boyes and Thompson, 1937]. Therefore, any diploid egg in *S. officinarum* in a 2*n* embryo-sac stands a greater chance of being fertilized and producing viable seeds. The haploid fertilized eggs would then be nonviable. For the same reason, diploid pollen grains are less functional in producing triploid progenies.

(*g*) *Consequences of polyploidy*

Doubling of chromosome sets during gametogenesis in *S. spontaneum* is associated with an increase of size of the various parts in the auto-triploids, followed by an increase in its yielding capacity [Janaki Ammal, 1939]. The same chromosome complement has a quantitatively and qualitatively different phenotypic expression when represented different number of times. The triploid mutants of *S. spontaneum* are known to be 'giants'.

Doubling of chromosomes during gametogenesis, leading to non-reduction, is of great importance in the synthesis of new species and widely separated genera. Thus in the trigeneric triple hybridization only those hybrids of *Triticum dicoccum* × *Haynaldia* would cross with *Secale cereale* through functioning of unreduced female gametes [Kostoff and Arutjunova, 1937]. The doubling of chromosomes could be utilized as a means of increasing the crossability between plants and overcoming non-crossability [Karpechenko, 1936]. This fact is of considerable importance in plant breeding as this would serve to bring together a combination of desired characters found in different species and genera. In the words of Karpechenko [1927], 'To learn how to increase arbitrarily the number of polyploid gametes, to learn how to pick out the latter and use them for crossing, is a very alluring task'.

Summary

1. Megasporogenesis in the two species of *Saccharum* have been critically studied. Meiosis in megaspore-mother-cells follows the normal course.

2. Occasionally the innermost megaspore of a tetrad and more commonly the inner haploid dyad cell develop into the embryo-sac.

3. Diploid megaspores are formed by fusion of two inner haploid megaspore nuclei of the spore-tetrad and more commonly observed in *S. officinarum*.

4. Both haploid and diploid embryo-sacs develop and are of the normal eight-nucleate type.

5. Normal and triploid embryos in *S. officinarum* are formed by fertilization of haploid and diploid egg cells.

6. Diploid parthenogenesis and nucellar embryony are recorded in *S. officinarum*.

7. Various abnormalities, like a reversal of the embryo-sac, presence of two egg cells in embryo-sacs, secondary embryo-sacs in the same nucellus, uni-nucleate or binucleate 'antipodal' egg cells, are observed in both the species.

8. Evidences for the origin of triploid mutants and triploid hybrids of *Saccharum* through non-reduction, reunion of daughter-nuclei or splitting of chromosomes in haploid egg cells have been presented.

9. The reunion of two megaspore-nuclei is related as equivalent to a 'sexual fusion' of gametes or 'fertilization' and probably accounts for a non-recurrent parthenogenesis in *Saccharum*.

10. Viability of embryos in *Saccharum* has been found to be probably related to the degree of polyploidy of maternal tissue and endorsperm.

Acknowledgements

For guidance, helpful criticisms and kindly interest throughout the progress of the work, I wish to express my grateful thanks to Dr E. K. Janaki Ammal, M.A., D. Sc., Sugarcane Geneticist, Imperial Sugarcane Breeding Station, Coimbatore. Thanks are also due to Rao Bahadur T. S. Venkatraman, C.I.E., B.A., I.A.S., Government Sugarcane Expert, Imperial Sugarcane Breeding Station, Coimbatore, for kindly providing me with the necessary facilities to work in this Institute.

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THE DISTINGUISHING CHARACTERS AND BEHAVIOUR OF SOME GRAPE VINE VARIETIES INTRODUCED AT LYALLPUR IN THE PUNJAB

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(Received for publication on 29 October 1939)

(With three text-figures)

Introduction

THE grape has almost invariably found a place in the orchards throughout the Punjab, but its cultivation never assumed that commercial importance which is meted out to some other fruits. This may be due chiefly to the cultivation of such varieties as happened to be unsuited to the conditions prevailing and, as such, did not bear crops of that delicious quality for which the fruit from Quetta and Chaman (as known in commerce) has made a name. Obviously the first step to the improvement of this important fruit necessitated the trial of a large number of varieties growing under diverse conditions in various parts of the world to see which of them could be acclimatized profitably and then supplement it by the evolution of new varieties through hybridization. With these aims in view, one hundred and ten varieties were obtained from California, New York, Russia, Australia, Quetta, Peshawar, Nasik and also from some places in the Punjab. The varieties obtained from California include several that are also popular in Palestine and France, those obtained from Russia unfortunately did not survive and those from New York have been planted only recently and it is thus too early to give any authentic information regarding them.

The varieties imported got mixed up somehow, with the result that at the time of fruiting an admixture of several distinct varieties was noticed in rows of most of them. This presented difficulties not only in the matter of recording yields but alsoin actually ascertaining which individualin any particular row to label by the name under which it was originally received. In order to avoid confusion, the different varieties were assigned an identity designation till they were isolated, for which even the standard books on the subject [Bailey, 1922; Hedrick, 1919; 1922; Munson, 1909; Perold, 1927] did not help matters to any appreciable extent, as these works put together do not contain the description of more than a dozen and a half of the varieties reported in this paper. This naturally necessitated the carrying out of detailed investigations into their morphological characters with a view to isolate

them properly and further utilize the data for hybridization work. The importance of the work of this kind is well recognized in the horticulturally advanced countries of the world , where botanical characters of the varieties under cultivation are recorded from time to time and the information, in course of time, forms an asset both to the grower and the investigator.

In India there is a great dearth of literature on the subject particularly with regard to this fruit, which is almost a monopoly of British Baluchistan and Afghanistan at present. In planning the investigational work reported herein, the treatise on viticulture by Perold [1927] was found to be a valuable guide. The technical terms used in describing a vine are, therefore, largely those that are already well recognized in other grape-growing countries of the world.

The investigations reported herein were carried out over a period of five years (1933-37). The mass of descriptive data, collected during this period, has been properly arranged to facilitate easy reference, the arrangement of description being identical for all the varieties. It is hoped that the data, reported in this paper, would be useful in many ways to the research workers, growers and nurserymen. The relative importance of various parts of a vine responsible for giving the varieties their distinguishing characters is discussed and a key to their identification is prepared on that basis. The key thus constructed and reported herein is both easy of adoption and exhaustive inasmuch as it can help to isolate all the varieties in the collection at Lyallpur. Nevertheless the scope of its use may possibly extend to a further lot of varieties in the matter of diagnosing them. Furthermore, the descriptive notes regarding each variety would equip the beginners against undue waste of time and money in the matter of introducing new varieties for trial as the same can be supplied from Lyallpur. This would also help the investigators in their work of breeding new varieties, besides proving of practical importance in the naming of stray varieties, purchasing varieties true to name and detecting the presence of ' rogues '. Much of the confusion regarding correct nomenclature would also be avoided.

Material used

The grape vine varieties, growing in the experimental garden at Lyallpur, that were obtained from California, Australia, Quetta, Peshawar, Nasik, and some places in the Punjab, served as the material for these investigations. The plants were set in their permanent places in the spring of 1928. The soil is sandy loam alluvial. All varieties were trained by three systems of pruning viz. head, cane and cordon, but the descriptions given herein relate to the vines trained on trellis and pruned to ' cane system ' [Bioletti, 1922 ; Pb. Agric. Coll. Mag.; 1935] as all the varieties responded best for cropping to this system.

Methods employed

Study of the following parts of the vine was made in each case on the lines set forth as under :—

(*1*) *General vigour*.—The vigour of the different varieties growing in the collection area was described as ' vigorous ', ' medium ', and ' poor ' according to the general appearance of the plant based on the thickness of trunk and length and thickness of canes.

(2) *Unfolding leaves.*—The colour and pubescence of unfolding leaves was recorded quite early in the growing season for each variety.

(3) *Growing shoots.*—The degree of pubescence on growing shoots was oted early in the growing season, viz. months of April and May. The pubese nt shoots are graded as glabrous, cobwebby, downy and felt-like as ollo ws :—

(a) Glabrous.—When the pubescence is almost wanting.

(b) Cobwebby or slightly pubescent.—When the pubescence extends to the first five nodes reckoned from the tip of the shoot.

(c) Downy or fairly pubescent.—When the pubescence extends over the first ten internodes.

(d) Woolly or strongly pubescent.—When the pubescence extends over more than ten internodes.

(4) *Full-grown leaves.*—For a study of the leaf characters only those leaves were selected that were fairly uniform in shape. Such a condition was found to exist in almost all the varieties in case of 9th to 12th leaves counted from the base of the shoot. It may also be noted that the range of occurrence of the leaves of uniform shape was considerably more in case of the vigorously growing varieties. Such observations as leaf shape (Fig. 2), pubescence, dentition, pubescence and colour of leaf nerves, colour and pubescence of petiole, etc. were made separately for each variety. The pubescent leaves are classed as :—

(a) Glabrous.—When the pubescence is almost wanting except a slight amount of it being present on the nerves on the lower surface of lamina.

(b) Downy.—When there is only a fair amount of pubescence which can be rubbed off easily.

(c) Felt-like.—When the pubescence on the lower surface of the leaf is dense giving it a woolly white appearance and withstands rubbing.

(5) *One-year-old wood* (*canes*).—The properties of the ripened wood were noted after the leaves had dropped in order to see how far they could help in distinguishing varieties. Their study consists of describing the colour, shades and pubescence if persisting. To study the length of internodes ten shoots were taken in case of each variety, which has been described as short, medium-long and long as under :—

Short.—Average length of internodes up to 3·0 cm.

Medium-long.—Average length of internodes from 3·1 to 4·5 cm.

Long.—Average length of internodes over 4·5 cm.

(6) *Flowers.*—The varieties were described as having perfect or imperfect flowers, depending upon the presence or absence of essential parts.

(7) *Bunches and berries.*—Detailed notes on shape, size and compactness of bunches ; size and toughness of peduncle ; size and condition of pedicel ; shape of berries, colour and condition of skin, condition and taste of pulp ; number, colour and shape of seeds, etc., for each variety, were recorded (*Vide* glossary).

Presentation of results

(*1*) *Vigour of varieties.*—All the varieties growing in the collection have been placed into three groups, viz. vigorous. medium and poor. It may be mentioned at the outset that the varieties behave differently with respect to this character under diverse conditions but in a collection at any particular place the degree of vigour may give the varieties a distinguishing character. It, therefore, follows that vigour is a feature of relative importance only and its utility is limited to the comparison of varieties growing side by side when conditions are uniform and soil heterogeneity is at its minimum. This character, therefore, has not been employed to classify them.

(*2*) *Unfolding leaves.*—The colour and pubescence of unfolding leaves along with the colour of margins was found to be a useful guide for differentiating varieties, but this was, however, possible only by comparing side by side the growing tips of shoots. This feature provides such a wide range of variation that individuals of no two varieties under study looked alike, but it is to be noted that it is extremely difficult to describe the colour shades and degrees of pubescence, with the result that for diagnostic purposes the descriptive notes regarding this feature were of little use. If, however. coloured diagrams could be made, this character, perhaps, would serve to differentiate varieties better than several other features taken singly.

(*3*) *Growing shoots.*—The growing shoots are either green or have purplish colour in them. The purple colour may either be in streaks or it may be predominating in the region of the growing tips. The degree of pubescence on the two types of canes generally met with varies considerably. The data regarding the classification of varieties under study according to colour and pubescence of green shoots is set out in Appendix I. It would be seen at a glance that comparatively a small number of varieties have purely green coloured shoots, but a large majority of them have purple colour in them. This feature is not so outstanding for the identification of varieties as some others described hereafter. If, however, the data is used in conjunction with other features, the classification of varieties can be greatly facilitated.

(*4*) *Full-grown leaves.*—As stated previously. 9th to 12th leaves on the canes reckoned from the base were employed for noting the shape and pubescence of leaves for all the varieties under trial. Such leaves were invariably found to be of uniform shape and size if growing normally. In Appendix II the varieties have been grouped according to the shape and pubescence of leaves thus studied. With the exception of *Agawam*. the shape of leaves of the remaining varieties is either orbicular or cuneiform (Fig. 2). The varieties having these three forms of leaves are further grouped according to the degree of pubescence on the lower surface of leaves, viz. glabrous, downy, or felt-like. All the varieties under study thus fall into seven groups.

(*5*) *One-year-old wood.*—Notes on the character of one-year-old wood are compiled in Appendix III. This character, when used in conjunction with others, is quite helpful in identifying varieties.

(*6*) *Bunches and berries.*—This, perhaps, provides the best single feature for diagnostic purposes and is also quite easy of accurate description. No two varieties look alike with respect to the character of bunches and berries. The berry characters constituting colour and shape are set out in Appendices

IV and V, respectively. Both of these characters have been found to be very helpful in identifying varieties.

There is always a certain amount of variation in the colour and shape of berries. For instance under ' light purple ' column (Appendix IV) not only the varieties having light purple colour are included but also others that are either red or reddish. Similarly under ' green ' column, varieties having green and yellowish green berries are included ; and under ' light green ' column, varieties having light green, greenish yellow, pale green and yellowish white colour, etc. are included. The shape of berries also varies to some extent in nearly all the varieties, especially in case of those that bear compact bunches. For study of shape, therefore, berries from fairly loose bunches or loose parts of the compact bunches were invariably taken so as to exclude those having abnormal shape from berry shape study.

Notwithstanding all this, certain unsurmountable difficulties were experienced, e.g. in the case of spherical berries there were some slightly deviating from the perfect spherical shape but had to be classed as spherical. The same difficulty was experienced in case of the short-oval and oval-shaped varieties. It is, however, considered advisable to class varieties having short-oval shape as distinct from those having oval shape but also to refer to some other distinguishing characters in cases of dispute.

Description of varieties.—The varieties have been arranged and described in their alphabetical order.

Agawam

Vines.—Of medium vigour.

Shoots.—Medium-thick, medium-long, rough ; colour red in streaks on green ; pubescence strongly woolly ; internodes medium-long ; tendrils medium-long, pubescent, trifid, discontinuous ; tips of growing shoots brownish green ; young leaves appear white due to dense pubescence on both surfaces, margin green.

Canes.—Smoky, angular, bark peeling off.

Leaves.—Dark green on upper but light green on lower surface, thick, rough ; shape cordate ; pubescence downy on upper but felt-like on lower surface ; leaf entire, petiolar sinus slightly open below, others missing ; teeth very broad and pointed ; terminal tooth broad, rounded and pointed ; nerves thick greenish yellow with pinkish dots, strongly pubescent, stalk very thick, yellowish green with pink shades, pubescence downy.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick and tough ; bunches medium, long, pyramidal, single, loose or compact, even ; pedicel short, thick and warty ; berries medium to large, spherical ; skin purple, thick and leathery ; berry content quite pulpy sweet with a peculiar mango flavour ; seeds dark brown, 2-4 per berry.

A light to medium cropper ; ripens during the month of July.

Angulata

Vines.—Vigorous.

Shoots.—Thick, medium-long, rough ; colour dark purple ; pubescence densely woolly ; internodes medium-long ; tendrils short, pubescent, bi- or

trifid, intermittent ; tips of growing shoots brownish green ; young leaves yellowish green, margin reddish green, pubescence on both surfaces.

Canes.—Smoky on one side and light brown on the other, angular, bark sound.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape cuneiform ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar and other sinuses well marked ; small and bigger teeth irregularly alternating, medium ; nerves medium-thick, strongly pubescent, yellowish green ; stalk short, thick, strongly pubescent, light green and pink in patches.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thin or medium-thick, soft and brittle ; bunches medium or large-sized, long, irregular, divided, very loose, fairly even ; pedicel long, thick and warty ; berries small or medium-sized, spherical ; skin pinkish yellow, thick and leathery ; berry content juicy, a bit acidic, quality fair, seeds brown, about two per berry.

A light to medium cropper ; ripens in July.

Australian

Vines.—Of medium vigour.

Shoots.—Thin, short, rough ; colour yellowish green with pink lines ; pubescence downy ; internodes medium-long ; tendrils medium-long, bi- or trifid, wooly, discontinuous ; tips of growing shoots reddish green ; young leaves yellowish green, margin red near the tips of teeth.

Canes.—Colour brown on one and greyish yellow on the other side, angular.

Leaves.—Dark green on upper surface but light green on lower one, small, thick and rough ; shape cuneiform ; almost glabrous ; 5-lobed, petiolar sinus open and cup-shaped, basal and lateral sinuses also well marked and V-shaped ; teeth narrow, small ones alternating with bigger ones, terminal tooth very narrow, long and pointed, nerves thin, pinkish, strongly woolly ; stalk short, thick, pink, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick, tough ; bunches medium-sized, long, pyramidal, single, fairly compact ; ripening even ; pedicel short, thick and warty ; berries medium-sized, spherical ; skin purple with blue bloom, thick and leathery ; berry content pulpy, firm and sweet ; quality fair ; seed colour reddish brown, 2-4 per berry.

A light cropper ; ripens about the beginning of July.

Bakator

Vines.—Vigorous.

Shoots.—Thick, medium-long, rough ; colour dark purple on upper but green on lower surface ; pubescence densely woolly ; internodes medium-long ; tendrils short, pubescent bi- or trifid, intermittent ; tips of growing shoots brownish green ; young leaves yellowish green, margin reddish green, pubescence on both surfaces.

Canes.—Brown on one and greyish yellow on the other side, angular.

Leaves.—Dark green above but light green on lower surface, thick, rough ; shape cuneiform ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar and other sinuses well marked, U-shaped ; teeth narrow, long and pointed, and terminal tooth very long and pointed ; nerves medium-thick, strongly pubescent, colour yellowish green ; stalk short, thick, strongly pubescent, colour light green and pink in patches.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thin or medium-thick, soft and brittle ; bunches medium or large-sized, long, irregular shape, divided, loose ; ripening fairly even ; pedicel long, thick and warty ; berries small or medium-sized, spherical ; skin pinkish yellow, thick, leathery ; berry content juicy, a bit acidic, quality fair ; seed colour brown, about two per berry.

A medium cropper ; ripens from the end of June to the third week of July.

Beau Blanc

Vines.—Of poor vigour.

Shoots.—Short, medium-thick, rough ; colour green with red streaks ; pubescence woolly (very small hair) ; internodes short ; tendrils short, bifid, pubescent, intermittent ; tips of growing shoots brownish green ; unfolding leaves greenish yellow, margin pink, pubescent on both surfaces.

Canes.—Smoky, angular, bark sound.

Leaves.—Dark green on upper but light green on lower surface, medium-thick, rough ; shape orbicular ; pubescence downy on lower surface but glabrous above ; 5-lobed, petiolar sinus closed above by basal lobes but open below, basal sinuses less marked than lateral ones ; teeth large, broad and pointed ; terminal tooth narrow, tapering and pointed ; nerves yellowish green having pink or brown shades, pubescent, thin ; stalk short, thin, colour yellowish green with pink shades, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thin, tough ; bunches small or medium-sized, long, pyramidal, single, compact ; ripening even ; pedicel medium-long, thin and warty ; berries small, spherical or short-oval ; skin translucent, yellow or pinkish yellow, medium-thick, cracking ; berry content juicy, mild sweet and of good flavour ; quality fair ; seeds brown, 2 to 3 per berry.

A light cropper ; ripens from the third week of June to the beginning of August.

Bedana

Vines.—Vigorous.

Shoots.—Thick, long, rough ; colour purple on upper but green on lower surface ; pubescence cobwebby ; internodes medium-long ; tendrils long, pubescent, trifid, intermittent ; tips of growing shoots pale green ; young leaves yellowish green, margin of the same colour, pubescent on both surfaces.

Canes.—Smoky angular, bark sound.

Leaves.—Green on upper but light green on lower surface, medium-thick ; shape orbicular glabrous on both surfaces ; 5-lobed, petiolar sinus closed above

but slightly open in the middle, basal and lateral sinuses not well marked, V-shaped ; teeth acute and pointed ; terminal tooth acute and pointed ; nerves thin, light pink but red near their point of origin on the upper surface, slightly pubescent ; stalk short, thin, green with purple streaks, glabrous on both surfaces.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick and brittle ; bunches large-sized, long, pyramidal, single, compact ; ripening fairly even ; pedicel medium-long, thin and warty ; berries small-sized, oval ; skin greenish yellow, medium-thick and cracking ; berry content a bit firm, sweet and of good flavour, seedless.

A medium cropper ; ripens from the middle of June to the middle of July.

Bellino

Vines.—Of medium vigour.

Shoots.—Medium-thick, medium-long and rough ; colour bluish red in patches or lines on green shoots ; pubescence densely woolly ; internodes medium-long ; tendrils short, pubescent, bifid, intermittent ; tips of growing shoots brownish green, woolly. ; unfolding leaves yellowish green, woolly, margins tinted red.

Canes.—Smoky on one side and light brown on the other, round, bark sound.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus closed above by basal lobes but open below, basal and lateral sinuses well marked, U-shaped ; teeth narrow and pointed, small and big ones irregularly alternating ; terminal tooth long, narrow and pointed ; nerves thin, yellowish green with pink shades, 1st and 2nd laterals red near their point of origin, strongly woolly ; stalk light purple, short, medium-thick, pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and tough ; bunches medium-sized, long, pyramidal, single, compact ; ripening even ; pedicel short, thick and warty ; berries medium to large-sized ; shape spherical or short oval ; skin thick, dark purple with blue bloom, leathery ; berry content a bit firm, juicy and sweet ; seeds dark brown 2 to 3 per berry.

A light to medium cropper ; ripens from the middle of June to the middle of July.

Bhokari

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; colour dark purple with green lines or shadss ; pubescence woolly ; internodes long ; tendrils medium, pubescent, bifid, intermittent ; tips of growing shoots brownish green ; young leaves purplish green, margin red, pubescence on both surfaces.

Canes.—Purple, round, pubescence persisting.

Leaves.—Dark green on upper but light green on lower surface, medium-thick and rough ; shape cuneiform ; pubescence glabrous on both surfaces ;

5-lobed, basal sinuses less marked than others ; teeth long, narrow and pointed terminal tooth long, narrow and pointed ; nerves thin, greenish yellow with pink dots ; on upper surface of the lamina the nerves are purple till the point where tertiary nerves arise, but on the lower surface the second lateral nerves are purple only near their point of origin ; stalk short, thin, dark purple with green shades, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick, tough ; bunches medium to large-sized, long, pyramidal, usually single, fairly compact, ripening even ; pedicel long, medium-thick, smooth and brittle ; berries large, spherical ; skin greenish yellow, thick and leathery ; berry content juicy, mild sweet, quality fair ; seeds well developed, brownish black, 1-2 per berry.

A heavy cropper ; ripens from the end of June to the end of July.

Black Damascus

Vines.—Vigorous.

Shoots.—Long, thick and rough ; dark purple shades or lines on green ; pubescence strongly woolly ; internodes medium-long ; tendrils medium-long, bifid, pubescent and intermittent ; tips of growing shoots, brownish-green, strongly woolly ; unfolding leaves greenish-white with red margins, dense pubescence on both surfaces.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus closed above but open below, other sinuses well marked ; there is a tooth developed at the base of lateral sinuses ; teeth in two series, small ones regularly alternating with large, broad and pointed ones ; terminal tooth long, narrow and pointed ; leaf nerves strongly pubescent, medium-thick and pinkish yellow in colour but the middle and lateral nerves turn purple at the tips, second lateral nerves purple near their point of origin till the point where the tertiary nerves arise ; leaf stalk green with dark purple shades, short, medium thick and slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick and tough ; bunches medium or large-sized, short, pyramidal, single and fairly loose ; ripening fairly oven ; pedicel medium-long, thick and warty ; berries medium to large-sized, oval ; skin dark purple with blue bloom, thick and cracking ; berry content a bit firm, melting and sweet ; flavour and quality good ; seeds of brown colour well-developed, 2 to 3 per berry.

A light to medium cropper ; ripens from the beginning to the third week of July.

Black Prince

Vines.—Vigorous.

Shoots.—Long, thick and rough ; colour mostly green with dark purple bands on nodes and streaks on internodes ; pubescence downy ; internodes short ; tendrils medium to long, bi- or trifid, pubescent and intermittent ; tips of growing shoots yellowish green, pubescent ; unfolding leaves, yellowish green with pink margins, pubescence on both surfaces.

Canes.—Smoky on purple back-ground, round.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 3-lobed, petiolar sinus open, but lateral sinuses not very well marked: teeth in two series, small ones regularly alternating with large, broad and pointed ones ; terminal tooth long, narrow and pointed ; leaf nerves medium-thick, pinkish yellow and pubescent ; leaf stalk short, medium-thick, yellowish green with purple shades and pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-thick, medium-long, and tough with or without a lateral bunch ; bunches medium or large-sized, long, pyramidal, single or divided, loose or compact ; ripening even ; pedicel thin, long and warty ; berries large or medium-sized, shape spherical ; skin dark purple with blue bloom, thick and leathery ; berry content separates in a mass from the skin, juicy, sweet and of distinct and good flavour ; very good quality ; seeds well developed, 1 to 3 per berry.

A medium cropper ; ripens from the middle of June to the middle of July.

Black Prince (Calif.)

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; dark purple shades or streaks on green : pubescence densely woolly ; internodes medium-long ; tendrils long, tri-tetra or pentafid, strongly pubescent, intermittent ; tips of growing shoots brownish green ; young leaves greenish white, margin red.

Canes.—Smoky on purple back-ground, round.

Leaves.—Dark green on upper but light green on lower surface, medium, slightly rough ; shape cuneiform ; pubescence downy on both surfaces : 5-lobed, petiolar sinus cup-shaped, other sinuses closed above but open below ; teeth either narrow or broad ; terminal tooth long, narrow and broad ; nerves thin, greenish yellow with pink dots on lower surface but purple near their point of origin on upper surface, pubescent ; stalk thick, flattened, dark purple with green streaks ; slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, tough ; bunches usually large, long, pyramidal, single, fairly compact ; ripening fairly even ; pedicel thick, medium-long and warty ; berries medium or large-sized, spherical ; skin of light purple colour with blue bloom thick and leathery ; berry content firm, melting and sweet, quality good ; seed brownish green, well-developed, 2-4 per berry.

A medium cropper ; ripens from the end of June to the end of July.

Black Hamburg

Vines.—Vigorous.

Shoots.—Medium thick, long, rough ; colour green ; pubescence cob-webby ; internodes short ; tendrils medium-long, slightly pubescent, trifid, intermittent ; tips of growing shoots yellowish green ; unfolding leaves greenish yellow, margin pink, pubescence on both surfaces.

Canes.—Purple, angular.

Leaves.—Dark green on upper surface but light green on lower one, thick and rough ; shape cuneiform ; pubscence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus well marked, cup-shaped, others well marked, U-shaped ; teeth large, narrow and pointed ; terminal tooth very narrow, long and pointed ; nerves thick, greenish yellow with pink dots, strongly pubescent ; stalk medium-thick, medium-long, dark purple shades mixed with yellowish green, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick, tough ; bunches medium or large-sized, long, pyramidal, single, usually loose ; ripening even ; pedicel thin, long and warty ; berries medium or large-sized, spherical or short oval ; skin purple or dark purple with blue bloom, thick and leathery ; berry content separates in a mass from the skin, more juicy than Black Prince, sweet but flavour not as distinct as in the case of Black Prince ; seed dark-brown, well-developed, 1-2 per berry.

A medium to heavy cropper ; ripens from the 3rd week of June to the end of July.

Bückland's Sweet Water

Vines.—Medium vigour.

Shoots.—Medium-thick, medium-long, rough ; colour mostly green but dark purple lines also ; pubescence downy ; internodes short ; tendrils, pubescent, medium-long, trifid, intermittent ; tips of growing shoots greenish yellow with brown shades ; young leaves greenish yellow, margin pinkish, pubescence on both surfaces.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green above but light green below, thick, and rough ; shape orbicular ; glabrous on both surfaces ; 5-lobed ; all sinuses well marked ; teeth broad and pointed ; terminal tooth narrow and pointed ; nerves thin, slightly pubescent, colour greenish yellow with pink dots ; stalk short, thin, slightly pubescent, colour light green with pink shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick and tough ; bunches medium to large-sized, long, pyramidal, divided, usually loose ; ripening even ; pedicel long, thick, warty ; berries medium to large-sized, short oval or spherical ; skin greenish yellow or pinkish yellow, medium-thin, cracking ; berry content a bit firm, melting and sweet ; quality good ; seed light black, 2-3 per berry.

A medium cropper ; ripens from the middle of June to the middle of July.

Chak 45 G. B.

Vines.—Very vigorous.

Shoots.—Thick, long and rough ; dark purple lines on green ; pubescence woolly ; internodes medium-long ; tendrils short, bi- or trifid, woolly, intermittent ; tips of growing shoots brownish yellow ; unfolding leaves yellowish green, margin pinkish, pubescence on both surfaces.

Canes.—Light brown, angular, thick.

Leaves.—Dark green on upper surface but light green on lower one, medium-thick ; shape orbicular ; almost glabrous on both surfaces ; 5-lobed. petiolar sinus closed above but open below, other sinuses marked, U-shaped ; teeth small or large, narrow ; terminal tooth broad and pointed ; nerves thick, pubescent, greenish yellow with pink shades ; stalk short, thick, slightly pubescent, colour dark purple with creamy yellow shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thin and tough ; bunches small, short, loose, single ; ripening even ; pedicel long, thick and warty ; berries large-sized, cylindrical ; skin yellowish green with white bloom, thick and cracking ; berry content pulpy, firm and mild sweet ; seed dark brown, 1-2 per berry.

A light cropper ; ripens about the end of July or the beginning of August.

Chasselas Rose

Vines.—Poor vigour.

Shoots.—Thin, short to medium-long, rough ; greenish yellow ; pubescence downy ; internodes short ; tendrils short, trifid, pubescent, intermittent ; tips of growing shoots brownish green with purple colour at the nodes ; unfolding leaves reddish green, margin red, pubescence woolly on both surfaces.

Canes.—Brown on one side and greyish yellow on the other, round.

Leaves.—Dark green on upper surface but light green on lower one, thick ; shape orbicular ; pubescence downy on lower surface but glabrous on upper one ; 5-lobed, all sinuses well marked, V-shaped ; teeth broad, rounded at the top and pointed ; terminal tooth narrow and pointed ; nerves thin, purple near their point of origin but purplish green above, pubescent ; stalk short, thin, pubescent, colour yellowish green with pink shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thin or medium-thick, tough ; bunches small to medium-sized, long, shouldered, pyramidal, single, generally compact ; ripening fairly uniform ; pedicel short, medium-thick and warty ; berries small to medium-sized, spherical ; skin pink or pinkish green, thick, leathery ; berry content slightly pulpy, melting and sweet, flavour good ; seed dark brown, flattened shape, generally two per berry.

A light to medium cropper ; ripens from the middle of June to the 3rd week of July.

Chaouch

Vines.—Very vigorous.

Shoots.—Thick, very long, rough ; colour dark purple ; pubescence strongly woolly ; internodes long ; tendrils long, strongly pubescent, bifid, intermittent ; tips of growing shoots brownish green ; young leaves appear paper white on both surfaces due to strong pubescence, margin deep-red.

Canes.—Purple, round, pubescence persisting.

Leaves.—Green above but appear greenish white on lower surface due to strong pubescence, margin red ; shape cuneiform ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, all sinuses well marked ; teeth either narrow or broad ; terminal tooth long, narrow and pointed, nerves

thick, dark purple near their point of origin but greenish yellow above, strongly woolly ; stalk fairly long, thick, deep purple, strongly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick, tough ; bunches generally large-sized, long, shouldered, pyramidal, single, compact ; ripening fairly even ; pedicel short, thick and warty ; berries large-sized generally, slightly oval ; skin yellowish green, medium-thick, cracking ; berry content soft, juicy, mild sweet ; seed brownish yellow, well developed, 3 to 4 per berry.

A medium to heavy cropper ; ripens from the middle of June to the beginning of July.

Cornichon

Vines.—Vigorous.

Shoots.—Medium-thick, medium-long and rough ; colour yellowish green with purple shades on the upper surface ; pubescence cobwebby ; internodes medium-long ; tendrils long, trifid, slightly pubescent, intermittent ; tips of growing shoots light green, pubescent ; unfolding leaves yellowish green, margin green, strongly pubescent on upper surface.

Canes.—Smoky on purple back ground, angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; glabrous on both surfaces ; 5-lobed, all sinuses well marked ; teeth mostly narrow and pointed ; leaf nerves thick, pinkish yellow, downy pubescence on both surfaces ; leaf stalk medium-thick, pink shades on green, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, medium-thick and tough ; bunches medium-sized, broad, divided, loose and uneven ; pedicel long, thick and warty ; berries medium-sized, long, ovoid ; skin pink, thick and leathery ; berry content puply, with flat taste ; seeds dark brown, 2-3 per berry.

A very light cropper ; ripens about the end of July.

Cipro Nero

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; colour dark purple having yellowish green streaks or patches ; pubescence downy ; internodes medium-long ; tendrils long, trifid, pubescent, discontinuous ; tips of growing shoots brownish green ; young leaves yellowish green, margin pink, pubescence on both surfaces.

Canes.—Purple, angular.

Leaves.—Dark green on upper but light green on lower surface, thick, rough ; shape cuneiform ; pubescence downy on both surfaces ; 5-lobed, petiolar sinus well marked, cup-shaped, other sinuses also well marked ; teeth broad or very broad, terminal tooth also broad. Nerves creamy yellow with pink shades but purple near their point of origin, second laterals more purple than others, medium-thick, pubescent ; stalk thick, short, purple with green shades, pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick, tough ; bunches medium or large-sized, long, pyramidal, single, fairly loose ; ripening fairly even but

colour of berries does not change uniformly ; pedicel, medium-long, medium thick and warty ; berries medium-sized, oval ; skin light purple or purple, thick and cracking ; berry content melting and sweet ; flavour pleasant ; seeds dark brown, 2-3 per berry.

A light cropper ; ripens about the middle of July.

Dakh

Vines.—Very vigorous.

Shoots.—Long, thick and rough ; colour dark purple, pubescence woolly ; internodes medium-long ; tendrils medium-long, strongly woolly, bifid and intermittent ; tips of growing shoots brownish green, densely pubescent, unfolding leaves greenish yellow with red margins, pubescence woolly.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark green on the upper surface but light green below, thick and rough ; shape orbicular, downy on the upper but felt-like on the lower surface ; 5-lobed, petiolar sinus closed above but open below, lateral sinuses open, U-shaped, basal sinuses slightly open ; teeth narrow, long and pointed, small and large ones irregularly alternating ; terminal tooth very long, narrow and pointed ; leaf nerves densely pubescent, medium-thick, purple on both sides—the intensity of colour decreasing towards the apex ; leaf stalk thin short and dark purple, pubescence downy.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick and tough ; bunches medium, long, pyramidal, single or divided, compact and even ; pedicel short, thick and warty ; berries medium-sized, usually spherical, skin black with blue bloom, thick and leathery ; berry content juicy and fairly acidic ; seeds 2-3 per berry, but sometimes more.

A very heavy bearing variety, good for juice making ; ripens from the third week of June to the third week of July.

Damas Rose

Vines.—Very vigorous.

Shoots.—Medium-thick, long and rough ; bluish-red lines on green ; pubescence cobwebby ; internodes medium-long ; tendrils medium-long, trifid, pubescent, intermittent ; tips of growing shoots reddish green, pubescent ; unfolding leaves yellowish green, margin light pink, dense pubescence on both surfaces.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, all sinuses well marked ; teeth in two series, small and large ones irregularly alternating, terminal tooth broad and pointed ; nerves medium-thick, greenish-yellow with light pink shades ; leaf stalk short and thick, colour comprises mixed light purple and yellowish green shades, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-thick, medium-long and fairly tough ; bunches medium or large-sized, pyramidal, single and fairly

compact ; ripening fairly even ; pedicel medium-long, thick and warty ; berries large-sized—larger than all other varieties ; shape spherical ; skin light rose coloured. medium-thick and cracking ; berry content a bit firm, melting juicy and sweet ; quality good ; seeds 2-5 per berry but not well-developed.

A light to medium cropper : ripens from the middle of July to the first week of August.

Danugue

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; colour dark purple in patches or lines on green ; pubescence cobwebby ; internodes long ; tendrils long, trifid, pubescent, intermittent ; tips of growing shoots reddish or brownish green ; young leaves yellowish green, margin purple, pubescent.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark purple on upper but light green on under surface, thick ; shape cuneiform, almost glabrous on both surfaces, 5-lobed, petiolar sinus cup-shaped and other sinuses open and well-marked ; teeth broad and narrow ; terminal tooth long, narrow and pointed ; nerves thick, yellowish green, slightly pubescent ; stalk short, thick, greenish yellow with pink dots, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick and fairly brittle ; bunches medium or large-sized, short or long, pyramidal, single, fairly compact ; ripening fairly uneven ; pedicel medium-long, medium-thick and warty ; berries medium to large-sized, spherical ; skin light pink to dark purple, thick and cracking ; berry content a bit firm, melting and sweet ; seeds dark brown, 2-3 per berry.

A light to medium cropper ; ripens in the month of July.

Diamond Jubilee

Vines.—Vigorous.

Shoots.—Medium-long, thick, angular and rough ; colour dark purple, pubescence wooly ; internodes medium-long ; tendrils short, wooly, mostly bifid, intermittent ; tips of growing shoots purple with dense pubescence ; unfolding leaves light purple offering white shade due to dense pubescence, margin pink.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark green on upper surface but light green on lower one, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on the lower surface ; 5-lobed, petiolar sinus closed above due to basal lobes but prominent, other sinuses less marked ; teeth in two series—small ones alternating with big, broad, rounded ones ; leaf nerves prominent on lower surface, densely pubescent, colour creamy yellow but red near their point of origin upto a length of about half an inch ; leaf stalk reddish purple, short, thick and pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and brittle ; bunches small to medium-sized, short or long, mostly divided, loose and even ;

pedicel long, thick and warty ; berries large, short oval or spherical ; skin medium-thick, black with blue bloom, cracking ; berry content firm, pulpy, insipid ; quality poor ; seeds two to three per berry, well developed and of green colour.

A medium cropper ; ripens from the beginning to the end of July.

Dizmar

Vines.—Vigorous.

Shoots.—Thick, long and smooth ; dark purple lines on green ; pubescence downy ; internodes medium-long ; tendrils medium-long, trifid, pubescent, discontinuous ; tips of growing shoots purplish green ; unfolding leaves greenish yellow offering pink shade, margin pink, pubescent on both surfaces.

Canes.—Light brown, angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; leaves glabrous on upper surface but downy on lower one ; 5-lobed, petiolar sinus open, other sinuses also well marked; teeth broad or very broad, terminal tooth narrow ; nerves thin, colour creamy yellow with pink shades, slightly pubescent ; petiole purple with green shades, thin, short, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thin and tough ; bunches medium-sized, long, pyramidal, single, loose ; ripening even ; pedicel medium-long, medium-thick, warty ; berries medium-sized, oval ; skin pinkish or brownish yellow, thick and cracking ; berry content quite firm, pulpy and sweet ; seed brown, 1-2 per berry.

A light cropper ; ripens from the middle of June to the beginning of July.

Doite-de-dessie

Vines.—Of medium vigour.

Shoots.—Thick, medium-long, rough ; colour green ; pubescence cobwebby ; internodes medium-long ; tendrils short, trifid, slightly pubescent, discontinuous ; tips of growing shoots greenish yellow ; unfolding leaves greenish yellow, margin red, pubescent on both surfaces.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface thick and rough ; shape cuneiform ; almost glabrous ; 5-lobed, all sinuses well marked ; teeth narrow or broad, long and pointed ; terminal tooth very long, narrow and pointed ; nerves thick, creamy yellow with pink shades, pubescent ; stalk short, thick, yellowish green with pink shades, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick, brittle ; bunches medium, short, single or divided, fairly loose, even ; pedicel long thick and warty ; berries medium or large, obovate, skin greenish yellow with white bloom, thick and brittle ; berry content pulpy, firm and sweet, good flavour ; fairly good quality ; seeds small, dark brown, 1-2 per berry.

A very light cropper ; ripens about the end of July.

Fakadi

Vines.—Very vigorous.

Shoots.—thick, long, rough ; dark purple lines on green ; pubescence woolly ; internodes medium-long ; tendrils long, bi- or trifid, pubescent, intermittent ; tips of growing shoots yellowish green ; unfolding leaves yellowish green, margin red, pubescence on both surfaces.

Canes.—Purple, angular.

Leaves.—Dark green above, but light green on the lower surface, thin ; shape orbicular ; pubescence downy on upper surface but glabrous on lower surface ; 3-lobed, petiolar sinus well marked, lateral sinuses less marked ; small teeth regularly alternating with large, broad and pointed ones ; terminal tooth narrow and pointed ; nerves thin, greenish yellow with pink dots, pubescent ; stalk short, thin, light purple with green shades, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick and brittle ; bunches usually large-sized, long, pyramidal, single, very loose ; ripening uniform ; short berries found in almost every bunch ; pedicel long, medium-thick and warty ; berries medium-sized, oval ; skin yellowish green, thick and cracking ; berry content juicy, mild sweet, no flavour ; seed dark brown, small sized, 2-4 per berry.

A heavy cropper ; ripens from the beginning to the end of July.

Foster's Seedling

Vines.—Of poor to medium vigour.

Shoots.—Medium-thick, short to medium-long, rough ; colour mostly green but sometimes dark purple bands on nodes and lines on internodes ; almost glabrous ; internodes medium-long ; tendrils medium-long, bifid, almost glabrous, intermittent ; tips of growing shoots greenish yellow, unfolding leaves pinkish green, margin green, no pubescence.

Canes.—Purple, round.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; almost glabrous on both surfaces ; 3-lobed, petiolar sinus almost closed, lateral sinuses slightly marked ; teeth small or large, broad, rounded ; terminal tooth long and narrow ; nerves medium-thick, pinkish yellow, pubescent on lower surface ; stalk long, thick, slightly pubescent, colour yellowish green with purple shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick, fairly brittle ; bunches medium or large-sized, long, pyramidal, generally single, loose, shot berries in the bunch characteristic of the variety ; ripening fairly even ; pedicel long, medium-thick, warty ; berries medium-sized, spherical ; skin yellowish green, thick, leathery ; berry content firm, slightly pulpy but melting ; very sweet, excellent flavour ; one of the best varieties under trial ; seed dark brown, 2-4 per berry.

A medium to heavy cropper ; ripens from the middle of June to the beginning of July.

Gatak

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; colour bluish red and green mixed in patches ; pubescence cobwebby ; internodes medium-long ; tendrils pubescent, medium-long ; bifid, intermittent ; tips of growing shoots green ; young leaves greenish yellow, margins reddish green but sinuses red tinged, pubescent.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, medium-thick and rough ; shape cuneiform ; almost glabrous on both surfaces ; 5-lobed, petiolar sinus open and well marked but lateral and baisal sinuses not well marked ; teeth large, broad, rounded and pointed ; terminal tooth broad, rounded and pointed ; nerves thin, greenish yellow, slightly pubescent, lateral nerves red near their origin ; stalk short, thick, pink, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick, fairly brittle ; bunches medium, short, pyramidal, single, fairly loose, even ; pedicel short, thick and warty ; berries medium-sized, spherical with deep depression at stigma-end that changes the shape to irregular ; skin thick, cracking and of pale yellow colour ; berry content a bit firm, melting and sweet, hollow around the seed ; seeds brown, 1-2 per berry.

A very light cropper ; ripens about the middle of July.

Gros Colman

Vines.—Vigorous.

Shoots.—Medium-long, medium-thick and rough ; growing habit erect ; colour purple ; pu escence wooly ; internodes long ; tendrils long, bifid, strongly pubescent and intermittent ; tips of growing shoots light purple to brownish and densely pubescent ; unfolding leaves appearing white due to dense pubescence, margins light green.

Canes.—Smoky on purple back-ground, round.

Leaves.—Dark green on upper but light green looking whitish due to pubescence on lower surface, thick and rough ; shape orbicular ; pubescence on both surfaces, downy above but felt-like below ; 3-lobed or almost entire, petiolar sinus closed above by basal lobes but open below, other sinuses not marked ; teeth slightly narrow, rounded and pointed ; terminal tooth narrow but round and pointed above ; nerves creamy yellow in colour, prominent, thick and strongly pubescent ; second lateral nerves red upto the point from where tertiary nerves arise out of them ; leaf stalk short, thick, light purple and pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thin and fairly tough ; bunches small, short, loose and single ; ripening fairly even ; pedicel short, thick and warty ; berries medium to large-sized ; shape spherical ; skin thick, cracking and dark purple changing to bluish black ; berry content firm and sweet ; seeds 3-4 per berry and well developed.

A medium to heavy cropper ; ripens from the third week of July to the 2nd week of August.

Gros Sapat

Vines.—Poor to medium in vigour.

Shoots.—medium-long, medium-thick and rough ; colour brownish yellow ; pubescence cobwebby ; internodes medium-long ; tendrils small, bifid, pubescent and intermittent ; tips of growing shoots yellowish green, slightl pubescent ; unfolding leaves greenish yellow, pubescent on both surfaces, margin pink.

Canes.—Smoky on purple back-ground, round.

Leaves.—Dark green on upper but light green on under surface, thin and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surfaces ; 5-lobed, petiolar sinus closed above by basal lobes but open below, basal sinuses less marked than lateral ones ; teeth narrow and pointed, small and big ones irregularly arranged, terminal tooth long, very narrow and pointed ; nerves thin, brownish pale green, strongly pubescent, main and lateral nerves changing red at their tips ; leaf stalk greenish yellow with pink shades, short, medium and pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, medium-thick and tough ; bunches medium to large-sized, long, pyramidal, single, fairly compact ; ripening fairly even ; pedicel long, thin and warty ; berries medium to large-sized, spherical ; skin dark purple changing black, thin and leathery ; berry content separating in a mass from the skin, a bit acidic ; quality fair ; seeds 2-3 per berry.

A medium cropper ; ripens from the middle of June to the middle of July.

Green Large Seeded

Vines.—Vigorous.

Shoots.—Thick, long and rough ; dark purple lines on green ; pubescence cobwebby ; internodes medium-long ; tendrils medium-long, bifid, slightly pubescent, intermittent ; tips of growing shoots brownish green ; unfolding leaves yellowish green, margin pink, slightly pubescent.

Canes.—Light brown, angular.

Leaves.—Dark green on upper surface but light green on lower one, thin and soft ; shape orbicular ; no pubescence on either surface ; 5-lobed ; teeth narrow, small and big ones irregularly alternating ; terminal tooth long, narrow and pointed ; nerves medium-thick, greenish yellow with pink dots, slightly pubescent ; stalk medium-thick, short, colour yellowish green with pink shades, glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short or medium-long, thick and brittle ; bunches medium to large-sized, long, pyramidal, single, fairly compact ; ripening uniform ; pedicel short, thick, warty ; berries large-sized, long oval ; skin yellowish green, medium-thick, cracking ; berry content a bit firm, melting and sweet ; seed colour brown, size well developed, 21-per berry.

A very light cropper ; ripens about the second week of July.

Gujranwala

Vines.—Vigorous.

Shoots.—Long, thick, rough ; colour green ; pubescence wooly ; internodes medium-long ; tendrils medium-long, bifid or trifid, pubescent, intermittent ; tips of growing shoots yellowish green ; unfolding leaves greenish yellow, margin pinkish, pubescence on both surfaces.

Canes.—Purplish, angular.

Leaves.—Light green on upper surface but yellowish green on lower one, thick and rough ; shape orbicular ; glabrous on both surfaces ; 5-lobed, petiolar sinus closed above but open below, basal sinuses less marked, V-shaped, lateral sinuses open, U-shaped ; teeth large, broad, rounded and pointed ; terminal tooth long, narrow and pointed ; leaf nerves thin, slightly pubescent, pinkish yellow ; stalk short, thin, pinkish yellow, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick, tough ; bunches small or medium-sized, single, very loose ; ripening uniform ; pedicel long, thick and warty ; berries large-sized, cylindrical ; skin thin, yellow ; berry content slightly pulpy melting and sweet ; flavour not marked ; seed colour light brown, 1-2 per berry.

A very light cropper ; ripens about the middle of June.

Hur

Vines.—Very vigorous.

Shoots. Thick, long and rough ; colour mostly dark purple ; pubescence cobwebby ; internodes medium-long ; tendrils medium-long, bi- or trifid slightly pubescent, intermittent ; tips of growing shoots greenish purple ; young leaves brownish green with deep red margins, slightly pubescent.

Canes. Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thin, rough ; shape cuneiform ; pubescence downy on upper but felt-like on lower surface : 3-lobed, petiolar sinus well marked, open and cup-shaped, lateral sinuses V-shaped, basal sinuses very slightly marked ; teeth irregularly alternating, mostly broad, rounded and pointed, terminal tooth medium or broad and pointed ; nerves thin, greenish yellow, felt-like pubescence on lower surface, lateral nerves purple near their point of origin ; stalk short, thin, dark purple, not pubescent to the unaided eye.

Flowers —Hermaphrodite.

Characters of the bunch.—Peduncle long, thick and tough ; bunches medium or large-sized, long or broad, shouldered, usually single, fairly compact ; ripening even ; pedicel long, thick and warty ; berries medium to large-sized, short oval ; skin thin, cracking, of greenish yellow colour on which reddish brown shades develop ; berry content a bit firm, melting, sweet and of good flavour ; seeds well developed, of brownish yellow colour, 1-2 per berry.

A medium cropper ; ripens about the middle of July.

Hussaini Black Kabuli

Vines.—Very vigorous.

Shoots.—Thick, long and rough ; dark purple streaks on green ; pubescence woolly ; internodes medium-long ; tendrils medium-long, pubescent, bi- or trifid, intermittent ; tips of growing shoots yellowish green, pubescent ; unfolding leaves yellowish green with pink margin, white shade on both surfaces due to dense pubescence, changing purple later.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape cuneiform to orbicular ; pubescence downy on upper but felt-like on lower surface ; leaves without lobes but sometimes one or both lateral sinuses develop ; teeth in two series, small ones alternating with bigger ones, narrow or broad but are generally narrow ; leaf nerves medium-thick, pinkish-yellow with green shades and pubescent, second lateral nerves of purple colour on both surfaces upto the point where tertiary nerves arise ; leaf-stalks thick, pubescent and have purple and green shades on them.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and tough ; bunches medium-sized usually, long or short, divided, fairly loose and uneven ; pedicel short, thick and warty ; berries large and spherical ; skin black with blue bloom, thick and cracking ; berry content firm, pulpy and sweet ; quality fair ; seed content 2-3 per berry, colour light brown.

A light to medium cropper ; ripens from the end of June to the end of July.

Iona

Vines.—Of poor vigour.

Shoots.—Thin, short and rough ; colour green ; pubescence woolly ; internodes short ; tendrills short, bi- or trifid, pubescent, intermittent ; tips of growing shoots brownish green ; young leaves greenish white, margin green, lower surface pubescent.

Canes.—Smoky angular bark peeling off.

Leaves.—Dark green above but light green on lower surface, thick, rough ; shape cuneiform ; pubescence downy on upper but felt-like on lower surface ; 5-lobed ; petiolar sinus cup-shaped, others V-shaped ; teeth large, rounded and pointed ; terminal tooth narrow and pointed ; nerves thin, colour purplish near their point of origin but brownish or creamy yellow above, densely pubescent ; stalk thin, short, colour purple with yellowish shades, pubescence downy.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, medium-thick, tough ; bunches medium sized, long, pyramidal, single, fairly loose or compact ; ripening even ; pedicel short, medium-thick and warty ; berries medium-sized, spherical ; skin purple, thick and leathery ; berry content a bit pulpy, melting and sweet, mango flavour ; seed dark brown, 2-3 per berry.

A very light cropper ; ripens about the middle of July.

Jaishi

Vines.—Vigorous.

Shoots.—Thick, long and rough ; colour dark purple on upper but green on lower surface ; pubescence woolly ; internodes long ; tendrils very long, bi- or trifid, woolly, intermittent ; tips of growing shoots greenish white, unfolding leaves yellowish green, margins dark-red, woolly.

Canes.—Purple, angular, pubescence persisting.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus closed above but open below, basal sinuses V-shaped but lateral ones W-shaped ; small teeth regularly alternating with broad, rounded and pointed ones ; nerves thin, pinkish at the base, densely woolly ; leaf stalk short, medium-thick, purplish, densely pubescent.

Flower.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick and tough ; bunches medium to large-sized, long, shouldered, pyramidal, usually single, generally compact ; ripening fairly even ; pedicel medium-long, thick and warty ; berries medium-sized, oval ; skin greenish yellow on which brown shades develop, thick and cracking ; berry content juicy, a bit acidic ; quality inferior ; seeds of pinkish colour, usually 1-2 per berry.

A light to medium cropper ; ripens from the third week of June to the third week of July.

Kali Sahebi

Vines.—Vigorous.

Shoots.—Medium-thick, medium-long, rough ; dark purple streaks on green ; pubescence cobwebby ; internodes medium-long ; tendrills short, bi- or trifid, slightly pubescent, intermittent ; tips of growing shoots brownish yellow ; young leaves greenish yellow with red margins, slightly pubescent on both surfaces.

Canes.—Purple, angular.

Leaves.—Light green on upper but yellowish green on lower surface, thick, rough ; shape orbicular ; almost glabrous on both surfaces ; 5-lobed, petiolar sinus almost closed other sinuses well marked, U-shaped ; teeth large, broad, rounded and pointed ; terminal tooth long, very narrow and pointed ; nerves medium, creamy yellow with pink dots, slightly pubescent ; stalk short medium-thick, almost glabrous, creamy yellow with purple shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick, fairly brittle ; bunches medium-sized, long, pyramidal, single, fairly loose ; ripening fairly even ; pedicel long, medium-thick and warty ; berries large-sized, long (1·4 in.) ; shape irregular ; skin light purple, thin, cracking ; berry content firm, pulpy and sweet, flavour lacking ; seed colour brown, 1-2 well developed seeds per berry.

A very light cropper ; ripens in the beginning of August.

Kandhari

Vines.—Very vigorous.

Shoots.—Thick, long and rough ; colour light green ; pubescence cobwebby ; internodes medium-long ; tendrils long, slightly pubescent, bi- or

trifid, intermittent ; tips of growing shoots brownish green ; unfolding leaves yellowish green, pubescent, margins pink.

Canes.—Brown on one side and greyish white on the other, thick and vigorous.

Leaves.—Dark green on upper but light green on lower surface, thick ; shape orbicular ; glabrous on both surfaces ; 5-lobed, basal sinuses less marked than others ; teeth large, broad and pointed ; terminal tooth narrow ; nerves thin, pubescent, yellowish green with pink shades, second laterals pinkish on both surfaces upto the point where the tertiary nerves arise ; stalk short, thick, greenish yellow, glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick and tough ; bunches usually large-sized, loose or compact, pyramidal, single ; ripening fairly even ; pedicel long, thich and warty ; berries big-sized, long-oval ; skin purple, thick and cracking ; berry content sweet ; seeds well developed, 2-3 per berry.

A medium cropper ; ripens from the middle of June to the middle of July.

Kartilaska

Vines.—Very vigorous.

Shoots.—Thick, medium-long and rough ; dark purple lines on green back ground ; pubescence woolly ; internodes medium-long ; tendrils short, trifid, intermittent, strongly pubescent ; tips of growing shoots reddish green, looking white due to strong pubescence ; unfolding leaves reddish green, woolly, margins red.

Canes.—Purple, angular, pubescence persistent.

Leaves.—Dark green on upper but light green on under surface, thick and rough ; shape orbicular ; pubescence downy on both upper and lower surfaces ; 3-lobed, petiolar sinus well marked, U-shaped, lateral sinuses also clear, U-shaped ; teeth broad and pointed, small and big ones irregularly alternating ; nerves medium-thick, strongly pubescent, second lateral nerves red near their point of origin, but greenish yellow with pink shades above ; stalk short, thick and pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-thick and tough ; bunches mediun or large-sized, long, pyramidal, single, fairly compact ; ripening even ; pedicel long, medium thick and warty ; berries medium or large-sized, spherical ; skin greenish yellow with white bloom, thick and cracking ; berry content firm, pulpy, mild sweet with no flavour, seeds of brown colour, 2-3 per berry.

A light to medium cropper ; ripens from the second week of July to the beginning of August.

Khalili

Vines.—Vigorous.

Shoots.—Mostly thin, long, rough ; colour dark purple in patches or streaks on yellowish green ; pubescence downy on both surfaces ; internodes medum-lon g ; tendrills long, bifid, pubescent, intermittent ; tips of growing shoots brownish green, pubescent ; young leaves yellowish green margin pink, pubescent,

Canes.—Smoky on one side and brown on the other, angular, bark peeling off.

Leaves.—Dark green on upper but light green on lower surface, thin, soft; shape cuneiform ; pubescence downy on both surfaces ; 5-lobed, petriolar sinus well marked, basal sinuses less marked than lateral ones ; nerves thin, greenish yellow with pink dots, pubescent ; stalk short, thin, dark purple, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thin, tough ; bunches small or mediun-sized, long, pyramidal, divided, loose, ripening even ; pedicel long, thin and smooth ; berries medium-sized, long-oval ; skin yellowish green with white bloom, thin and cracking ; flesh soft, sweet but flavour not marked ; seed brownish yellow, 1-2 per berry.

A light cropper ; ripens in the beginning of June.

Kharimurat

Vines.—Vigorous.

Shoots.—Thick, medium-long, rough ; dark purple shades on green ; pubescence densely woolly ; internodes medium-long ; tendrils short, bi- or trifid, woolly, intermittent ; tips of growing shoots brownish green ; young unfolding leaves greenish yellow, pubescent on both surfaces, margin greenish yellow.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark green on upper but light green on lower surface, thick ; shape orbicular ; pubescence downy on lower surface but glabrous above ; 5-lobed, petiolar sinus closed above but open below ; basal sinuses less marked than lateral ones ; teeth narrow ; terminal tooth narrow and pointed ; nerves thin, greenish yellow with pink dots, pubescent ; stalk short, thin, purple coloured with light green shades, pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick, tough, bunches medium sized, long, cylindrical, loose ; pedicel long, thick and warty ; berries large-sized, long oval, spherical ; colour green ; berry content firm, pulpy and sweet but no flavour ; seed brownish yellow, 1-2 per berry.

A light cropper ; ripens from the beginning to the end of July.

Kishmish White

Vines.—Vigorous.

Shoots.—Thick, long, rough ; colour bluish red and green in patches ; pubescence cobwebby or downy ; internodes medium-long ; tendrils medium-long, pubescent, bifid, intermittent ; tips of growing shoots yellowish green ; young leaves greenish yellow, margin tinted pink ; pubescent slightly.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thick ; shape cuneiform ; almost glabrous ; 5-lobed, all sinuses equally well marked ; teeth broad, rounded and pointed ; terminal tooth narrow and pointed ; nerves greenish yellow with pink shades, pubescent ; stalk pink, short, thick, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and brittle, bunches medium-sized, long, shouldered, pyramidal, single, compact, even; pedicels short, thick and warty; berries medium-sized, oval; skin greenish yellow with brown or pink shades, thin, cracking; berry content juicy, sweet and of good flavour; seeds well developed, brownish yellow, usually one per berry.

A light cropper; ripens about the middle of June.

Luglinga

Vines.—Of poor vigour.

Shoots.—Thin, short, rough; colour green; pubescence downy; internodes medium-long; tendrils short, pubescent, bi- or trifid, intermittent; tips of growing shoots reddish green; young leaves greenish yellow offering pink shades, margin red, slightly pubescent.

Canes.—Smoky, round.

Leaves.—Dark green on upper but light green on lower surface, thick, rough; shape coneiform; pubescence downy on both surfaces; 5-lobed, petiolar sinus very broad and open, basal sinuses slightly marked but lateral ones well marked; teeth large, broad and pointed; terminal tooth long, narrow and pointed; nerves thin, greenish yellow with pink shades, woolly; stalk short, thin, green and brown shades, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick and tough; bunches small, single, compact, shouldered; ripening even; pedicels short, thick and warty; berries medium-sized, short oval; skin yellowish green with brown shades, medium-thick and cracking; berry content juicy and sweet; berries yellowish brown, 1-3 per berry.

A light cropper; ripens about the middle of June.

Madeleine Angevine

Vines.—Of medium vigour.

Shoots.—Medium-thick, long, rough; colour purple; pubescence woolly; internodes short; tendrils medium-long, bi- or trifid, woolly, intermittent; tips of growing shoots greenish purple changing entirely purple; young leaves yellowish green, margin tinted red, pubescence on both surfaces.

Canes.—Smoky, angular, bark peeling off.

Leaves.—Dark green on upper but light green on lower surface, thick and rough; shape cuneiform; pubescence felt-like on both surfaces; 5-lobed, all sinuses well marked and U-shaped; teeth long, narrow and pointed; terminal tooth long, very narrow and pointed; nerves thin, strongly woolly, colour purplish green but purple near their point of origin; stalk short, thin, dark purple, strongly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick, tough; bunches small to medium-sized, short, pyramidal, divided, loose; ripening even; pedical short, thick and warty; berries medium-sized, spherical; skin yellowish green, medium-thick and leathery; berry content soft, melting, juicy; berries translucent; seed brownish yellow to light black, well developed, 2-4 per berry

A light to medium cropper ; ripens about the first week of June and is the earliest ripening variety under trial.

Madresfield Court

Vines.—Very poor vigour.

Shoots.—Thin or medium-thick, very short and rough ; bluish pink shades on green ; pubescence woolly ; internodes short ; tendrils very short, bifid, woolly and intermittent ; tips of growing shoots pinkish green, densely pubescent ; unfolding leaves yellowish white, densely pubescent on both sides.

Canes.—Smoky, angular, pubescence persisting.

Leaves.—Darker green on upper than on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus closed above by basal lobes but prominently open below, other sinuses less marked and V-shaped ; teeth narrow, long and pointed ; terminal tooth very narrow, long and pointed ; leaf nerves densely pubescent, red near their places of origin and of light green colour having pinkish tinge, leaf stalk short, red and woolly.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thick, tough, without a lateral branch ; bunches small or medium-sized, short, pyramidal, single and compact ; uneven ripening is characteristic of this variety as green, light purple and dark purple berries can be found in every bunch ; pedicel short, thick and warty ; berries light or dark purple, medium or large-sized ; shape oval, berry content firm, melting, very sweet and of excellent flavour ; seeds one to two per berry and of green colour.

A light cropper ; ripens about the third week of July.

Malaga

Vines.—Vigorous.

Shoots.—Thick, long and rough ; dark purple patches or lines on green ; pubescence woolly ; internodes medium-long ; tendrils medium-long, pubescent, bi- or trifid, intermittent ; tips of growing shoots yellowish green with pink dots, pubescent ; unfolding leaves yellowish green, margin pink, pubescent.

Canes.—Light brown, angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, all sinuses well-marked, open, U-shaped ; teeth either broad or narrow, terminal tooth broad and pointed ; nerves medium-thick, creamy yellow with light pink shades, strongly pubescent ; lateral nerves purple coloured near their point of origin ; leaf stalk short, medium-thick, light purple with green shades, pubescent.

Flower.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick and brittle ; bunches medium to large-sized, long, pyramidal, single, fairly compact ; ripening even ; pedicel medium-long, thick and warty ; berries medium-sized, short oval ; skin greenish yellow, thick and cracking ; berry content pulpy, firm and fairly sweet ; seeds well developed, dark-brown coloured, 2-3 per berry.

A light to medium cropper ; ripens from the second week of July to the beginning of August.

Mavron

Vines.—Vigorous.

Shoots.—Long, thick and rough ; dark purple patches or lines on green ; pubescence woolly ; internodes long ; tendrils long, trifid, pubescent, discontinuous ; tips of growing shoots brownish green, young unfolding leaves purplish green, margin green, pubescent.

Canes.—Smoky on one side and light brown on the other, angular, bark peeling off.

Leaves.—Dark green on upper surface but light green on lower one, thin, rough ; shape orbicular ; pubescence downy on lower surface but glabrous on upper one ; 3-lobed, petiolar sinus closed above but open below, basal sinuses non-existent, but lateral ones slightly marked ; teeth large, broad and pointed ; terminal tooth long, narrow and pointed ; nerves thin, creamy yellow with pink shades, lateral nerves dark purple near their point of origin, pubescent ; stalk short, thin, dark purple with green shades, pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick and brittle ; bunches medium to large-sized, long, single, pyramidal, fairly loose ; ripening even ; pedicel medium-long, thin and warty ; berries small to medium-sized, short oval ; skin greenish yellow, thick and cracking ; berry content firm, pulpy and sweet ; quality fair ; seed bluish brown, well developed, 2-3 per berry.

A light to medium cropper ; ripens from the middle to the end of July.

Muscat of Alexandria

Vines.—Of medium vigour.

Shoots.—Thick, short, rough, colour green ; pubescence woolly ; internodes medium-long ; tips of growing shoots green ; young leaves appear white due to woolly pubescence, margin reddish ; tendrils long, pubescent, trifid or tetrafid, intermittent.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape cuneiform ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus well marked but basal and lateral sinuses less marked, V-shaped ; teeth large, narrow and pointed ; terminal tooth long, narrow and pointed ; nerves thick, greenish yellow, red near their origin, strongly pubescent on both surfaces ; stalk long, thick, pink, pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick, fairly tough ; bunches medium to large-sized, long, pyramidal, divided, loose ; ripening even ; pedicel long, thick and warty ; berries medium to large-sized, short-oval ; skin yellowish green, thick, cracking ; berry content a bit pulpy, melting, very sweet and of distinct muscat flavour ; quality good ; seed brownish green, 1-3 per berry.

A light to medium cropper ; ripens from the beginning to the end of July.

Palomino

Vines.—Vigorous.

Shoots.—Medium-thick, medium-long and rough ; colour dark purple ; pubescence woolly ; internodes medium-long ; tendrils medium-long, trifid, woolly, intermittent ; tips of growing shoots brownish green, pubescent ; unfolding leaves greenish yellow, margin pink, pubescence woolly.

Canes.—Smoky on one side and light brown on the other, angular, bark peeling off.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed ; all sinuses open and well marked ; teeth either narrow or broad, small and large teeth irregularly alternating ; terminal tooth long, narrow and pointed ; leaf nerves medium-thick, greenish yellow having pink shades, strongly pubescent, all nerves red near their point of origin on the upper surface of the leaf only ; leaf stalk medium-thick, short, dark purple with green streaks, pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick and brittle ; bunches medium or large-sized, long, pyramidal, divided, very loose ; ripening even ; pedicel long, thick and warty ; berries medium-sized, spherical ; skin yellowish green, thick and cracking ; berry content slightly firm, melting and sweet ; quality good ; seeds of dark brown colour, 2-3 per berry.

A medium to heavy cropper ; ripens from the end of June to the end of July.

Pandhari Sahebi

Vines.—Very vigorous.

Shoots.—Thick, long and rough ; colour green or dark purple shades on green ; pubescence cobwebby ; internodes medium-long ; tendrils long, trifid, pubescent, intermittent ; tips of growing shoots brownish green ; unfolding leaves greenish yellow, margin pink, pubescent.

Canes.—Brown on one side and greyish white on the other, thick and vigorous.

Leaves.—Dark green on upper but light green on lower surface, thick ; shape orbicular ; slightly downy pubescence on upper surface but glabrous on lower one ; 5-lobed, petiolar sinus almost closed, lateral sinuses more marked than basal ones ; teeth large, broad, round and pointed ; terminal tooth broad, dome-shaped and pointed ; nerves thick, colour greenish yellow with pink shades or dots, pubescent ; stalk short, very thick, greenish yellow with pink shades, glabrous.

Flowers.—Practically pistillate.

Characters of the bunch.—Peduncle medium-long or short, thick and tough ; bunches medium or large-sized, appearance attractive due to attractive colour of berries and compactness of bunches, long, pyramidal, single, compact ; ripening uniform ; pedicel long, thick and warty ; berries large-sized, long-oval ; skin yellow—with or without pink shades, thin, cracking ; berry content firm, pulpy, sweet but flavour lacking ; seed dark brown, 1-2 per berry.

A self-sterile variety, but medium to heavy cropper when grown with self fertile varieties ; ripens from the third week of June to the third week of July.

Pay Kani

Vines.—Vigorous.

Shoots.—Long, thick, rough ; dark purple lines on green ; pubescence cobwebby ; internodes long ; tendrils medium-long, bifid, slightly pubescent, intermittent ; tips of growing shoots brownish green ; young leaves greenish yellow, margin pinkish, pubescent.

Canes.—Light brown, angular.

Leaves.—Dark green on upper but light green on lower surface, thick ; shape cuneiform ; glabrous on upper surface but slightly pubescent on lower one ; 5-lobed, petiolar sinus considerably open and conspicuous but basal and lateral sinuses less marked ; teeth broad or narrow, pointed ; nerves thin, greenish yellow, slightly pubescent ; stalk short, thin, light green with pink shades slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick and fairly tough ; bunches medium to large-sized, long, pyramidal, divided, ripening uneven ; pedicel long, thick and warty ; berries large, oval ; skin yellowish green, thick and cracking ; berry content pulpy, melting and sweet ; seeds yellowish green with black tints, 1-2 per berry.

A light cropper ; ripens about the middle of July.

Portuguese Blue

Vines.—medium vigour.

Shoots.—Short, medium-thick and rough ; colour greenish yellow ; pubescence woolly ; internodes medium-long ; tendrils medium-long, trifid, pubescent, intermittent ; tips of growing shoots reddish green, pubescent ; unfolding leaves yellowish green, pubescent, margin yellowish green.

Canes.—Smoky on purple back ground, round.

Leaves.—Dark green on upper surface but light green on lower one, thin and slightly rough ; shape orbicular ; pubescence downy on both surfaces ; 5-lobed, petiolar sinus closed above but open below, basal and lateral sinuses open, U-shaped ; teeth narrow and pointed, small regularly alternating with big ones ; terminal tooth broad, round and pointed ; nerves thin, greenish yellow mixed with pink shades, lateral nerves pink near their point of origin ; stalk short, thin, yellowish green with pink shades, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick and tough ; bunches small to medium-sized, divided and very loose ; ripening uneven ; pedicel medium-long, thin and warty ; berries small and spherical ; skin thick, leathery, dark purple changing black with blue bloom ; appearance attractive ; flesh juicy, fairly sweet, flavour peculiar ; seed brownish green, 2-4 per berry, well developed.

A light cropper ; ripens from the middle of June to the third week of July.

Prunede Cazoul

Vines.—Vigorous.

Shoots.—Thin to medium-thick, rough ; colour yellowish green ; pubescence cobwebby ; internodes medium-long ; tendrils pubescent, medium-long, trifid, intermittent ; tips of growing shoots light green ; young leaves pinkish green, pubescent.

Canes.—Smoky on one side and light brown on the other, round.

Leaves.—Dark green on upper but light green on lower surface, thick ; shape cuneiform ; almost glabrous ; 5-lobed, petiolar and upper sinuses well marked but basal ones less marked ; teeth long, narrow and pointed ; terminal, tooth very long, narrow and pointed ; nerves thin, yellowish-green, pubescent, second lateral nerves red near their point of origin ; stalk short, thin, pink, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, medium-thick, fairly brittle ; bunches medium or large-sized, short, irregular, single, fairly loose ; ripening uneven ; pedicel medium-long, thick and warty ; berries medium or large-sized, oval ; skin green to dark purple, thick and leathery ; berry content a bit firm, juicy, melting and sweet ; quality fair, seed dark brown, 4-5 per berry.

A medium cropper ; ripens from the middle of July to the beginning of August.

Queen Golden

Vines.—Of medium vigour.

Shoots.—Short, medium-thick and rough ; colour dark purple ; pubescence woolly ; internodes short ; tendrils short, bi- or trifid, pubescent, intermittent ; tips of growing shoots brownish green, densely woolly ; unfolding leaves greenish yellow, woolly with red margins.

Canes.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, petiolar sinus closed above but open below, basal and lateral sinuses well marked, open, U-shaped ; teeth in two series, small ones alternating with large, broad and pointed ones ; nerves thick and strongly pubescent, purple near their point of origin but greenish yellow with pink shades above ; leaf stalk short, thick, dark purple and pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, medium-thick and brittle ; bunches medium or large-sized, long cylindrical or pyramidal, single and compact ; ripening even ; pedicel short, thick and warty ; berries large and spherical ; skin green with white bloom, medium-thick and cracking ; berry content a bit firm, melting, juicy and sweet ; seeds well developed, dark brown coloured, about 4 per berry.

A light to medium cropper ; ripens from the middle of July to the middle of August.

Ribier

Vines.—Very vigorous.

Shoots.—Medium-long, thick and rough ; dark purple patches on green ; pubescence woolly ; internodes medium-long ; tendrils long, pubescent, trifid and intermittent ; tips of growing shoots brownish green, densely pubescent ; unfolding leaves yellowish green with pink margin, strong pubescence on both surfaces.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper but felt-like on lower surface ; 5-lobed, but sometimes the tertiary nerves of second lateral nerves form two more lobes, making a total of seven ; petiolar sinus closed above but open below, other sinuses also marked ; teeth in two series, small ones alternate with big ones that are usually narrow, long and pointed ; terminal tooth long, narrow and pointed ; leaf nerves pubescent, thick and purple near their point of origin but creamy yellow mostly ; leaf stalk short, thick, flattened, pubescent, light purple with yellowish green shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and tough ; bunches large, long, pyramidal, single, loose and even ; pedicel medium-long, thick and warty, berries large and spherical ; skin jet-black with blue bloom, thick and cracking ; berry content firm, pulpy and sweet ; quality fairly good ; seeds 2-3 per berry and of dark brown colour.

A medium to heavy cropper ; ripens from the beginning to the end of July.

Rish Baba

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; colour dark purple and green mixed ; pubescence cobwebby slightly ; internodes medium-long ; tendrils long, bifid, slightly pubescent, intermittent ; tips of growing shoots brownish or reddish green ; young leaves greenish yellow with pink shades, margin pinkish, pubescent on both surfaces.

Cane.—Light brown but slightly smoky on one side, prominently angular.

Leaves.—Dark green on upper but light green on lower surface, medium-thick ; shape cuneiform ; glabrous on both sides ; 5-lobed, petiolar sinus cup-shaped, other sinuses open and well marked ; teeth reddish green ; broad and pointed ; terminal tooth long, narrow and pointed ; nerves thick, yellowish green with pink shades, pubescent ; stalk short, thick, light purple with green shades, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thin or medium-thick, brittle ; bunches medium or large, long, pyramidal, single, loose, even ; pedicel long or very long, medium-thick, warty ; berries large, long, long-oval ; skin greenish yellow with brown shades, thin or medium-thick, cracking ; berry content a bit firm, melting and sweet ; quality good ; seeds well developed, yellowish pink, 1-3 per berry.

A light cropper ; ripens during the month of July.

Rose

Vines.—Vigorous.

Shoots.—Medium-thick, long and rough ; colour red in lines on green ; pubescence cobwebby ; internodes long ; tendrils long, trifid, pubescent, intermittent ; tips of growing shoots yellowish green ; young leaves greenish yellow giving pinkish tinge, slightly pubescent on both surfaces, margin green.

Canes.—Purple, angular.

Leaves.—Dark green on upper but light green on lower surface ; fairly thick ; shape cuneiform ; almost glabrous on both surfaces ; 5-lobed, petiolar sinus open and cup-shaped, basal and lateral ones less-marked and V-shaped ; teeth broad and pointed ; terminal tooth large, broad and pointed ; nerves greenish yellow, slightly pubescent ; stalk short, thick, slightly pubescent, colour pink and yellowish-green in patches.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, tough ; bunches medium or large-sized, long, pyramidal, shouldered, divided, fairly compact ; ripening fairly uneven ; pedicel thick, long and warty ; berries medium to large-sized, oval ; skin medium-thick, colour red or light red (attractive), cracking ; berry content slightly pulpy, melting and sweet, flavour good ; seed dark brown, 1-2 per berry.

A very light cropper ; ripens about the middle of July.

Servan

Vines.—Very vigorous.

Shoots.—Medium-thick, long and smooth ; colour green ; pubescence woolly ; internodes medium-long ; tendrils long, pubescent, bi- or trifid, intermittent ; tips of growing shoots yellowish green, pubescent ; unfolding leaves greenish yellow, densely pubescent, margin green.

Canes.—Brown on one side and greyish-yellow on the other, angular.

Leaves.—Dark green on upper but light green on lower surface, medium-thick and rough ; shape orbicular ; pubescence on both surfaces ; 5-lobed, petiolar sinus nearly closed, basal and lateral sinuses open, U-shaped ; small teeth irregularly alternating with large, broad and pointed ones, terminal tooth long, narrow and pointed ; nerves thin, pinkish green, pubescent ; stalk short, thin, yellowish green, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and tough ; bunches medium or large-sized, long, pyramidal, fairly loose ; ripening uniform ; pedicel medium-long, thick and warty ; berries medium to large-sized, spherical ; skin light green, medium-thick and cracking ; seeds of dark-brown colour, 3-4 per berry.

A light to medium cropper ; ripens from the second week of July to the beginning of August.

Spin Savai

Vines.—Vigorous.

Shoots.—Thick, long and smooth ; colour mostly green but dark purple shades on green also ; pubescence cobwebby ; internodes long ; tendrils long,

trifid, slightly pubescent, intermittent ; tips of growing shoots light green ; young leaves yellowish green, margin pink, pubescence on both surfaces.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark green above but light green on lower surface, medium-thick ; shape orbicular ; both surfaces glabrous ; 5-lobed ; petiolar sinus well marked, lateral sinuses more marked than basal sinuses, and teeth-like structures develop at the base of lateral sinuses ; teeth large, broad and pointed ; terminal tooth long, narrow and pointed ; nerves thin, pubescence downy, colour dirty green or light green with pink dots.

Flowers.—Hermaphrodite.

Characters of the bunch.—Pedicels long, medium-thick and warty ; berries long-oval, large-sized ; skin greenish yellow, thin like that of 'bedana' variety, cracking ; berry content firm, melting and sweet, quality good ; seed content *nil* or 1-2 per berry, colour greenish yellow.

A very light cropper ; ripens about the beginning of July.

Sultana

Vines.—Vigorous.

Shoots.—Thick, long and smooth ; colour green ; pubescence downy ; internodes medium-long ; tendrils long, pubescent, bifid, intermittent ; tips of growing shoots yellowish green ; unfolding leaves greenish yellow, margin light pink, pubescent on both surfaces.

Canes.—Smoky, angular.

Leaves.—Dark green on upper but light green on lower surface, medium-thick ; shape orbicular ; both surfaces glabrous ; 5-lobed, petiolar sinus closed, other sinuses well marked, U-shaped ; teeth mostly broad ; terminal tooth long, narrow and pointed ; nerves thick, pubescence downy, colour greenish yellow with light pink shades and reddish near their point of origin on upper surface only ; stalk thick, short, greenish yellow with pink shades, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, brittle ; bunches large-sized, long, pyramidal, single, compact ; ripening fairly even ; pedicel medium long, thin, warty ; berries small, oval ; skin golden yellow, medium-thick, cracking ; berry content a bit firm, melting, sweet ; quality good ; seedless.

A light to medium cropper ; ripens from the middle of June to the beginning of July.

Sur Savai

Vines.—Vigorous.

Shoots.—Thick, long, smooth ; colour mostly green but sometimes dark purple shades also ; pubescence cobwebby ; internodes long ; tendrils long, trifid, slightly pubescent, intermittent ; tips of growing shoots brownish green ; unfolding leaves yellowish green, margin red, pubescent on both surfaces.

Canes.—Purplish, angular.

Leaves.—Dark green on upper but light green lower surface, medium-thick ; shape orbicular ; glabrous on both surfaces ; 5-lobed, petiolar sinus closed above but open below, other sinuses also marked ; teeth large, broad

and pointed ; terminal tooth long and narrow ; nerves medium-thick, light green with pink dots, pubescence felt-like, second lateral nerves red up to a little beyond the point of origin of tertiary nerves ; stalk short, thick, slightly pubescent, pinkish yellow with green shades.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, soft and brittle ; bunches medium or large-sized, long, pyramidal, single, loose or compact ; ripening even ; pedicel long, medium-thick and warty ; berries usually large-sized but small (shot) ones also met with in the same bunch, shape long-oval ; skin dark purple having blue bloom, thick, cracking ; berry content slightly firm, melting and sweet ; seeds well developed, usually one per berry and have yellow and blue pigments on them.

A light cropper ; ripens from the end of June to the 3rd week of July.

Tandah

Vines.—Vigorous.

Shoots.—Medium-thick, short, rough ; colour pinkish-green ; pubescence cobwebby ; internodes medium-long ; tendrils short, bifid, slightly pubescent, intermittent ; tips of growing shoots pinkish green ; young leaves greenish yellow, pubescent on both surfaces, margin green.

Canes.—Purple, round.

Leaves.—Dark green on upper but light green on lower surface, smooth and thin ; shape cuneiform ; slight pubescence on both surfaces ; 5-lobed, petiolar sinus well marked, open and cup-shaped, basal and lateral sinuses not marked, V-shaped ; teeth broad, rounded and pointed ; terminal tooth very broad, rounded and pointed ; nerves very thin, yellowish green, slightly pubescent ; stalk short, thin, pink, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, very tough ; bunches medium-sized, long, pyramidal, single, fairly loose ; ripening even ; pedicel medium-long, thick and warty ; berries medium to large-sized, oval ; skin pinkish or light red, medium-thick, cracking ; berry content juicy and sweet ; quality good, flavour not distinct ; seed yellow, 2-3 per berry.

A light cropper ; ripens about the second week of July.

Tas

Vines.—Vigorous.

Shoots.—Thick, long, smooth ; dark purple lines on green ; pubescence cobwebby ; internodes long ; tendrils short, bifid, slightly pubescent, intermittent ; tips of growing shoots light green ; young unfolding leaves yellowish green, margin red, pubescence on both surfaces.

Canes.—Purple, angular.

Leaves.—Dark green on upper surface but light green on lower one, medium-thick ; shape orbicular ; almost glabrous on both surfaces ; 5-lobed, petiolar sinus open below but closed above, other sinuses well marked ; lateral sinuses W-shaped ; teeth broad and pointed ; terminal tooth long, narrow and pointed ; nerves medium-thick, slightly pubescent, light green with pink dots ; second lateral nerves of dark purple colour upto the point where the tertiary nerves arise ; stalk short, medium thick, greenish purple, slightly pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, thick and tough ; bunches medium to large-sized, long, usually pyramidal, single, fairly compact ; ripening fairly even ; pedicel medium-long, thick, and warty ; berries medium to large-sized, short-oval ; skin greenish yellow, thick and cracking ; berry content firm, pulpy, mild sweet, no flavour ; seeds well developed, dark brown, 2 to 4 per berry.

A light to medium cropper ; ripens about the end of July.

Tor

Vines.—Vigorous.

Shoots.—Thick, long, rough ; colour mostly green ; pubescence downy ; internodes long ; tendrils pubescent, trifid, intermittent ; tips of growing shoots yellowish green ; young leaves yellowish green, margin pink, pubescent on both sides.

Canes.—Brown on one side and greyish yellow on the other, angular.

Leaves.—Dark green on upper but light green on lower surface, medium-thick ; shape cuneiform ; almost glabrous ; 5-lobed, petiolar sinus promi nent, open, cup-shaped but basal and lateral ones, V-shaped ; teeth broad ; terminal tooth long, narrow and pointed ; nerves medium-thick, pinkish green, pubescence felt-like on lower surface ; stalk medium-thick, pinkish, short, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, tough ; bunches large-sized, long, pyramidal, single, quite compact, ripening even ; pedicel short, thick and warty ; berries large-sized, short-oval or spherical ; skin black with blue bloom, thick and cracking ; berry content firm and sweet ; quality fair ; seeds well developed, light brown with bluish shades, 2-3 per berry.

A light to medium cropper ; ripens about the end of June.

Trentham Black

Vines.—Of medium vigour.

Shoots.—Medium-thick, long, rough ; dark purple shades or lines on green ; pubescence woolly ; internodes medium-long ; tendrils short, pubescent bifid, intermittent ; tips of growing shoots yellowish green ; young leaves pinkish green.

Canes.—Smoky, round.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape cuneiform, pubescence downy on both surfaces ; 5-lobed, petiolar sinus well marked, broad and open, basal sinuses less marked than lateral ones ; nerves medium-thick, yellowish pink and pubescent ; stalk short, thin, greenish yellow with purple shades, almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle medium-long, medium-thick, brittle ; bunches small to medium-sized, short or long, pyramidal, single, fairly loose ; ripening even ; pedicel medium-long, medium-thick and warty ; berries medium-sized, short-oval ; skin purple, thick and leathery ; berry content separates in a mass from the skin, melting and sweet ; seed dark-brown, 1 to 2 per berry.

A very light cropper ; ripens about the end of June.

Waltham Cross

Vines.—Very vigorous.

Shoots.—Thick, long, rough ; colour green ; almost glabrous ; internodes medium-long ; tendrils medium to long, bi- or trifid, almost glabrous intermittent ; tips of growing shoots green or brownish green ; young leaves yellowish green ; margin red, almost glabrous.

Canes.—Smoky on one side and light brown on the other, round.

Leaves.—Dark green on upper but light green on lower surface, thick; shape cuneiform ; almost glabrous on both surfaces ; 5-lobed ; petiolar sinus open and cup-shaped, lateral sinuses more marked than basal ones ; teeth large, broad, rounded and pointed ; terminal tooth long, narrow and pointed ; nerves medium-thick, greenish yellow with pink shades, slightly pubescent ; stalk short, medium-thick, yellowish green with pink shades ; almost glabrous.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle long, thick, tough ; bunches medium to large-sized, long, pyramidal, single, loose ; ripening uniform ; pedicel long, medium-thick and warty ; berries large, long-oval ; skin yellowish green with white bloom, thick and cracking ; berry content firm, pulpy and sweet ; quality good ; seeds well developed, brown coloured, 1-2 per berry.

A medium to heavy cropper ; ripens from the end of July to the beginning of August.

Zante Currant

Vines.—Vigorous.

Shoots.—Medium-thick, long and rough ; dark purple streaks on green ; pubescence woolly ; internodes medium-long ; tendrils long, bi- or trifid, densely pubescent and discontinuous ; tips of growing shoots greenish red, densely pubescent, unfolding leaves appear white due to pubescence on both surfaces, margin red, red colour develops after the leaves get slightly bigger.

Canes.—Purplish, angular.

Leaves.—Dark green on upper but light green on lower surface, thick and rough ; shape orbicular ; pubescence downy on upper surface but felt-like on lower one ; 5-lobed, petiolar sinus open and cup-shaped, basal and lateral sinuses less marked and v-shaped ; small and large teeth irregularly alternating and are mostly broad and pointed ; terminal tooth narrow and pointed ; leaf nerves thin and pubescent on both surfaces, lateral nerves dark purple near their places of origin on both surfaces but otherwise are of greenish yellow colour with pink dots ; leaf stalk short, thin, dark purple and densely pubescent.

Flowers.—Hermaphrodite.

Characters of the bunch.—Peduncle short, thin, soft and brittle ; bunches small or very small, long, pyramidal, divided, fairly loose and even ; pedicel long, very thin and smooth ; berries very small and spherical ; skin thin, purple coloured with blue bloom ; berry content juicy, very sweet and of good flavour ; seedless variety.

A light cropper ; ripens from the second week to the end of June.

Discussion of results and construction and use of the identification chart

An accurate and complete study of the character and properties of all the parts of grape vine varieties under trial has been made. Some of the descriptive data so gathered have been tabulated and discussed in the previous section from which it is evident that certain features of the vine are not as good a guide for diagnostic purposes as others, e.g. vigour and growth, which are only of relative importance, are helpful when the varieties are grown side by side in the collection. The other feature, i.e. degrees of colour shades, although an excellent guide to the identification of varieties in the field, yet cannot be usefully employed in describing varieties as degree of colour is very difficult to be recorded with precision. In constructing the identification chart, therefore, only such characters are employed as would be easy of adoption and afford a more or less constant specific value under diverse conditions. These features used in their order of importance are (*a*) leaf shape and pubescence, (*b*) colour of berries, (*c*) shape of berries, (*d*) colour of growing shoots and their pubescence, (*e*) cane characters and (*f*) some characters of peduncle, pedicel and skin (Appendix VI). Referring to the chart (Appendix VI) it is at once clear that all the varieties have only three forms of full-grown leaves, viz. orbicular, cuneiform and cordate (Fig. 2). Each of the three forms (shape) of leaf may have three degrees of pubescence, viz. (*a*) felt-like, (*b*) downy and (*c*) glabrous or no pubescence. It is thus evident that all the varieties can be classified into nine groups according to the shape and pubescence of full-grown leaves but actually all the varieties under trial at Lyallpur have fallen into seven groups. Except in one case, there are numerous varieties in each group, thus necessitating, a further classification according to some other outstanding features. This has been considerably accomplished by using the berry colour feature in conjunction with the leaf shape and pubescence inasmuch as the resultant sub-groups become small enough to be treated separately.

As may be expected, there are differences in colour shades and intensity of colour within the berry colour groups themselves. Besides, such shades are prone to vary slightly with season and locality. Due consideration was given to this aspect of the problem and no definite line of demarcation has thus been drawn between the colour groups as explained under ' Bunches ' and ' Berries ' in the previous section. The varieties falling in the various sub-groups have been further sorted out with the help of (*a*) shape of berry, (*b*) colour and pubescence of growing shoots, (*c*) character of canes and (*d*) some characters of peduncle, pedicel and skin and their importance for identification lies in the order in which they are written. It is evident that all the features enumerated above, when used conjointly in Appendix VI, have helped to isolate all the varieties under trial. It is hoped that this chart would help to isolate a further lot of varieties not reported in this paper.

There is yet another feature of interest afforded by the description of varieties. Although there are not more than a few varieties to select for commercial growing from the list reported in this paper, yet there are many that are outstanding with regard to one or the other most desirable feature. For instance *Madresfield Court*, *Black Prince* and *Muscat of Alexandria* are

noted for taste and aroma, *Dakh* and *Bhokari* are very prolific, *Pandhari Sahebi* excels every other variety for its attractive bunches and berries, *Damas Rose* is noted for the size of its berries and *Madeleine Angevine*, *Khalili* and *Kishmish White* are very early varieties. The desirable feature of these and such other varieties may be combined by making crosses between suitable parents, and the most desirable progeny seedlings may be multiplied by vegetative means. This type of work is now under way at Lyallpur as a result of the facilities provided by the Imperial Council of Agricultural Research.

Summary

(1) An accurate and complete study of the character and properties of all the parts of 66 grape vine varieties under trial has been made. It consists of the study of (*a*) vigour, (*b*) unfolding leaves, (*c*) growing shoots, (*d*) full-grown leaves, (*e*) one year-old wood and (*f*) bunches and berries.

(2) Some of the descriptive data so gathered have been tabulated and discussed from which it is evident that certain features of the vine are not as good a guide for diagnostic purposes as others.

(3) In constructing the identification chart, only such characters are employed as would be easy of adoption and afford, more or less, a constant specific value under diverse conditions. These features used in their order of importance are (*a*) leaf shape and pubescence, (*b*) colour of berries, (*c*) shape of berries, (*d*) colour of growing shoots and their pubescence, (*e*) cane characters and (*f*) some characters of peduncle, pedicel and skin.

(4) It is evident that all the features enumerated above, when used conjointly in Appendix VI, have helped to isolate all the varieties under trial.

Acknowledgements

The authors are indebted to various agencies for supplying the plant material, particularly to Professor Frederic T. Bioletti of the University of California who supplied no fewer than 60 varieties free of cost. Thanks are also due to Mr Sangat Singh, research assistant, who partly assisted in collecting, compiling and checking the data reported in this paper.

Mr. Ali Mohd. Qadri, artist, is responsible for the outline drawings of leaves and berries.

Glossary

A number of technical terms used in describing varieties have been explained in the section, ' methods employed ', but there are still others which need clarification to enable the reader to understand their significance fully. The following explanations illustrated by connotations and figures are given to serve the desired purpose.

Tendrils

The tendrils can be simple, bi-furcated or tri-furcated. In some varieties tetra-fid or even penta-fid tendrils are met with. In regard to their position on the cane, they are described as continuous, discontinuous or intermittent.

(*i*) *Continuous.*—When there is a tendril or a bunch opposite every leaf on the cane.

(*ii*) *Discontinuous or intermittent.*—When there is a tendril or a bunch opposite some leaves and no tendril or bunch against others, the arrangement can be termed either discontinuous or intermittent. It is called discontinuous when the discontinuity in the arrangement of tendrils is irregular, but when the discontinuity is regular, the arrangement is termed intermittent.

Leaf shape, nerves, lobes and sinuses, teeth, etc.

(*i*) *Leaf shape, nerves.*—The leaf can be of various forms or shapes depending upon the length of the primary or main nerve in relation to the first lateral nerve and the second lateral nerve (Fig. 1). The shape is also dependent on the angles made by the first lateral nerve with the primary nerve and by the first with the second lateral nerve. The leaves of the varieties described in this paper were either orbicular (round) or cuneiform (wedge-shaped), but in one instance they were cordate (heart-shaped). The forms of leaf may best be understood by referring to Fig. 2.

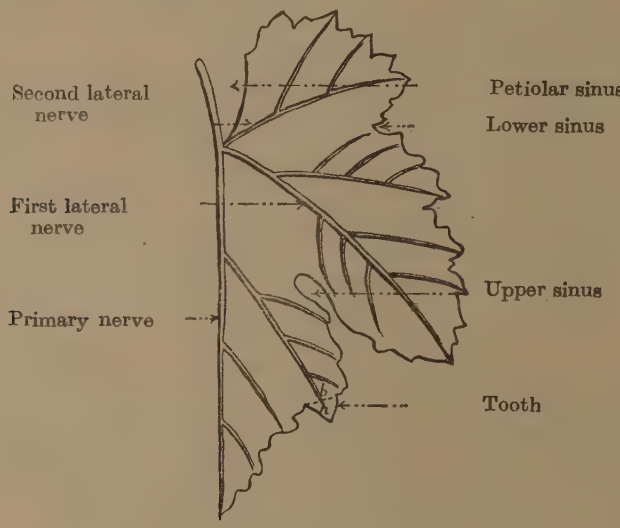

FIG. 1

(*ii*) *Lobing of the leaf and sinuses.*—The leaf can be entire, tri-lobed or five-lobed depending upon the number of sinuses present (Fig. 1). If the value of upper sinus is zero, the leaf is entire. If the upper sinus is clearly marked, the leaf is called five-lobed. In addition to the upper and lower sinuses, there is another sinus called the petiolar sinus, which is formed by the petiolar lobes.

(*iii*) *Teeth.*—The teeth can be of various forms depending upon the value of the ratio expressed by the height (h) of the teeth to its breadth (b) (Fig. 1).

The teeth are very narrow when the ratio is ≥ 1
The teeth are narrow when the ratio is $\geq 0 \cdot 75$
The teeth are broad when the ratio is $\geq 0 \cdot 50$
The teeth are very broad when the ratio is $\geq 0 \cdot 25$

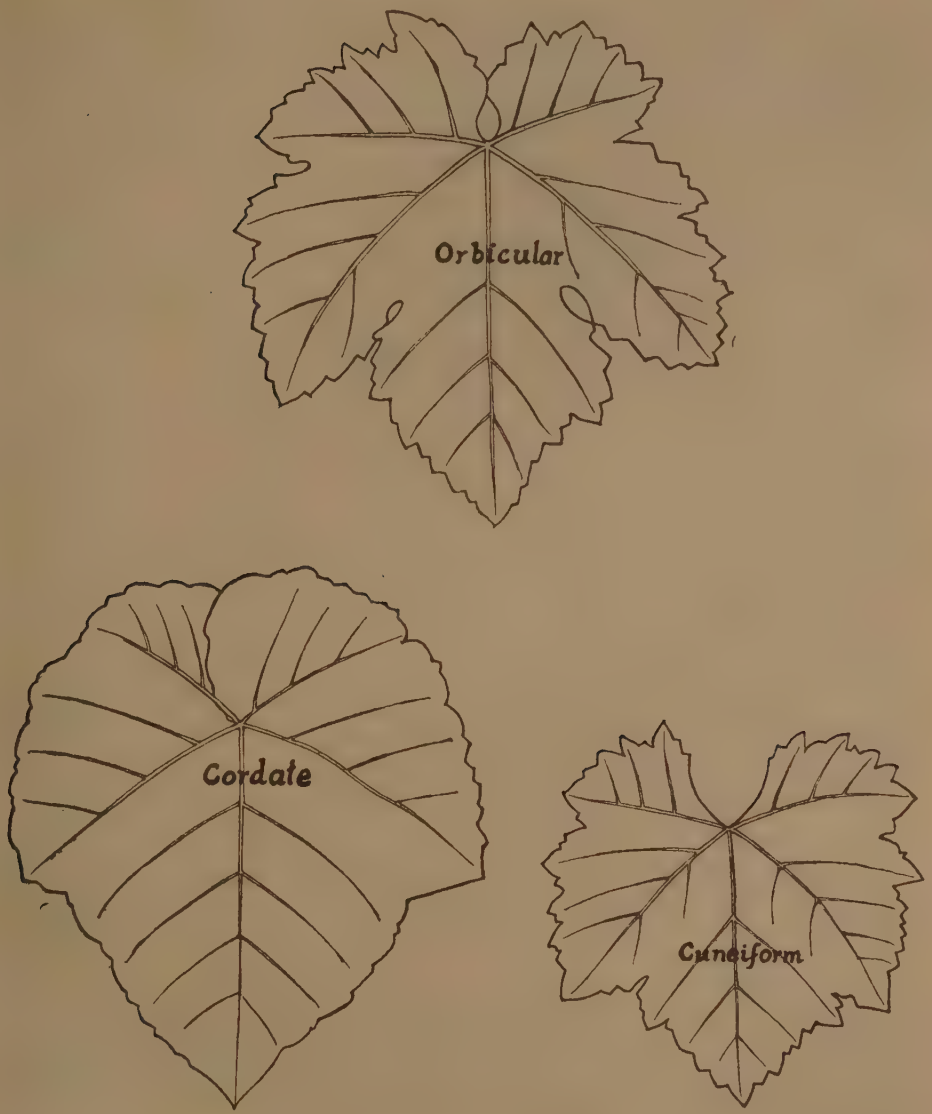

FIG. 2. Different forms of leaf

Description of bunches and berries

The bunch can be small, medium-sized or large-sized.

It is small when the average length diameter is ≤ 10 cm.

It is medium when the average length diameter is < 15 cm.

It is large when the average length diameter is > 15 cms.

The bunch can be long or short depending upon the value of the ratio expressed by its length to its breadth.

It is long when the ratio is > 1

It is short when the ratio is < 1

The bunch is called single, when there is no large stalk division. It is termed divided, when the large stalk division exists.

The bunch is called loose, when the berries can move freely in it. It is termed compact, when the berries are held, more or less, in fixed positions.

The ripening of the bunch is called even, when all the berries in it have ripened, more or less, uniformly. It is termed uneven, when ripe and unripe berries exist in one and the same bunch.

The size of the berry can be small, medium, large or very large depending upon its average diameter.

It is small when the average diameter is $\leq$10 mm.

It is medium when the average diameter is $\leq$15 mm.

It is large when the average diameter is $\leq$20 mm.

It is very large when the average diameter is $>$20 mm.

The shape of the berry can be spherical, short-oval, oval, long oval or irregular, depending upon the ratio of the long diameter to the cross one. To have an idea of the shapes as described in this paper, reference may be made to Fig. 3.

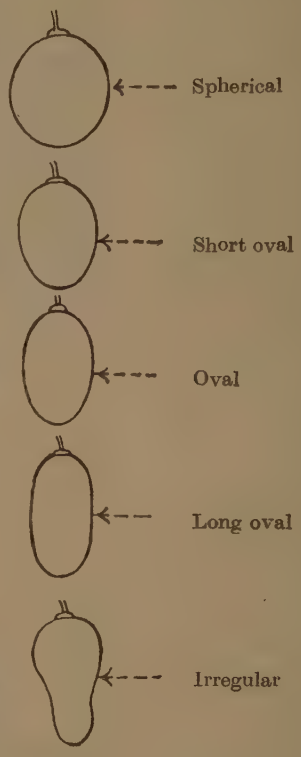

FIG. 3. Different shapes of berry

The skin is termed leathery, when it separates in a mass from the pulp while eating. It is called cracking, when it is crushed along with the pulp while eating.

Cropping propensities

A variety may be light cropper, medium or heavy cropper depending upon the average yield of fruit per vine. The cropping propensities of different varieties have been described on the basis of the average yield taken for the last five years (1933-1937) as follows :—

Very light cropper when the average yield	$\leq$3 lb.
Light cropper when the average yield	$\leq$6 lb.
Light to medium cropper when the average yield	$\leq$12 lb.
Medium cropper when the average yield	$\leq$16 lb.
Medium to heavy cropper when the average yield	$\leq$20 lb.
Heavy cropper when the average yield	$\leq$26 lb.
Very heavy cropper when the average yield	$>$26 lb.

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APPENDIX I

Grouping of grape vine varieties with respect to colour and pubescence of growing shoots

Green (devoid of other shades)				Green having purple shades slightly or predominating			
Woolly	Downy	Cobwebby	Glabrous	Woolly	Downy	Cobwebby	Glabrous
Gujranwala Iona Muscat of Alexandria Portuguese Blue Servan	Chasselas-Rose Luglinga Sultana Tor	Black-Hamburg Doite-de-Dessie Gros Sapat Kandhari. Prunede Cazoul	Waltham Cross	Angulata Agawam Bakator Beau Blanc Bellino Bhokari Black Damascus Black Prince (Calif.) Chak 45 G. B. Chaouch Dakh Diamond Jubilee Fakadi Gros Colman Hussaini Black-Kabuli Jaishi Kartilaska Kharimurat Malaga Madeleine Angevine Madresfield-Court Mavron Palomino Queen Golden Ribier Trentham Black Zante currant	Australian Black Prince Buckland's Sweet Water Cipro Nero Dizmar Kishmish-White Khalili	Bedana Cornichon Damas Rose Danugue Green Large Seeded Gatak Hur Kali Sahebi Pandhari Sahebi Pay Kani Rish Baba Rose Spin Savai Sur Savai Tandah Tas	Foster's Seedling

Appendix II

Grouping of grape vine varieties with respect to shape and pubescence of full-grown leaves

Orbicular (round)			Cuneiform (wedge-shaped)			Cordate (heart-shaped)		
Pubescent		Glabrous	Pubescent		Glabrous	Pubescent		Glabrous
Felt-like	Downy		Felt-like	Downy		Felt-like	Downy	
Bellino	Beau Blanc	Bedana	Angulata	Black Prince (Calif.)	Australian	Agawam	...	...
Black Damascus	Chasselas-Rose	Buckland's Sweet Water	Bakator	Cipro Nero	Bhokari			
Black Prince	Dizmar	Cornichon	Black Hamburg	Chaouch	Danugue			
Dakh	Fakadi	Chak 45 G. B.	Hur	Khalili	Doite-de-Dessie			
Damas Rose	Kartilaska	Fosters' Seedling	Iona	Luglinga	Gatak			
Diamond Jubilee	Kharimurat	Greend Large eeded	Madeleine-Angevine	Tandah	Kishmish-White			
Gros Colman	Mavron	Gujranwala	Muscat of Alexandria	Trentham-Black	Pay Kani			
Gros Sapat	Pandhari-Sahebi	Kali Sahebi			Prunede-Cazoul			
Hussaini Black-Kabuli	Purtuguese-Blue	Kandhari			Rish Baba			
Jaishi		Spin Savai			Rose			
Malaga		Sultana			Tor			
Madresfield-Court		Sur Savai			Waltham Cross			
Palomino		Tas						
Queen Golden								
Ribier								
Servan								
Zante Currant								

Bluish black and black
Bellino Dakh Diamond Jubilee Hussaini Black Kabuli Portuguese Blue Ribier Tor

Appendix III

Classifications of grape vine varieties according to the character of canes

Colour of canes smoky				Colour of canes smoky on one side and light brown on the other			Colour of canes smoky on purple background		Colour of canes light brown but slightly smoky on one side	Colour of canes light brown	Colour brown on one side and greyish white on the other	Colour brown on one side and greyish yellow on the other		Colour of canes purplish		Colour of cane purple			
Shape round	Shape angular			Shape round	Shape angular									Shape angular		Shape round		Shape angular	
	Bark peeling off	Bark sound																	
		Pubescence absent	Pubescence persisting	Bark sound	Bark sound	Bark peeling off	Shape round	Shape angular	Shape prominently angular	Shape angular	Thick and vigorous	Shape round	Shape angular	Pubescence absent	Pubescence persisting	Pubescence absent	Pubescence persisting	Pubescence absent	Pubescence persisting
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Luglinga. Trentham-Black	Agawam Iona Madeleine-Angevine	Beau Blanc Bedana Sultana	Madresfield-Court	Bellino Prunede Cazoul Waltham Cross	Angulata	Khalili Mavron Palomino	Black Prince (Calif.) Black Prince Gros Colman Gros Sapat Portuguese-Blue	Cornichon	Black Damascus Buckland's Sweet Water Damas Rose Doite-de-Dessie Gatak Hur Hussaini Black Kabuli Kishmish White Muscat of Alexandria Queen Golden Rish Baba	Chak 45 G. B. Dizmar Green Large-Seeded Malaga Pay Kani	Kandhari Pandhari-Sahebi	Chasselas Rose	Australian Bakator Dakh Danugue Diamond Jubilee Kharimurat Ribier Servan Spin Sava. Tor	Gujranwala Sur Savai Zante Currant	...	Foster's Seedling Tandah	Bhokari Chaouch	Black-Hamburg Cipro Nero Fakadi Kali Sahebi Rose Tas	Jaishi Kartilaska

Appendix IV

Grouping of grape vine varieties with respect to the colour of berries

Bluish black and black	Dark purple	Light purple and reddish, etc.	Green and yellowish green	Light green (greenish yellow and pale green, etc.)
Bellino	Australian	Agawam	Chak 45 G. B.	Beau Blanc
Dakh	Black Damascus	Angulata	Chaouch	Bedana
Diamond Jubilee	Black Hamburg	Bakator	Fakadi	Bhokari
Hussaini Black Kabuli	Black Prince	Black Prince (Calif.)	Foster's Seedling	Buckland's Sweet Water
Portuguese Blue	Gros Colman	Cornichon	Green Large Seeded	Doite-de-Dessie
Ribier	Gros Sapat	Chasselas Rose	Khalili	Gatak
Tor	Madresfield-Court	Cipro Nero	Kharimurat	Gujranwala
	Prunede Cazoul	Damas Rose	Luglinga.	Hur
	Sur Savai	Danugue	Madeleine Angevine	Jaishi
	Trentham Black	Dizmar	Muscat of Alexandria	Kartilaska
	Zante Currant	Iona	Palomino	Kishmish White
		Kali Sahebi	Pay Kani	Malaga
		Kandhari	Queen Golden	Mavron
		Rose	Waltham Cross	Pandhari-Sahebi
		Tandah		Rish Baba
				Servan
				Spin Savai
				Sultana
				Tas

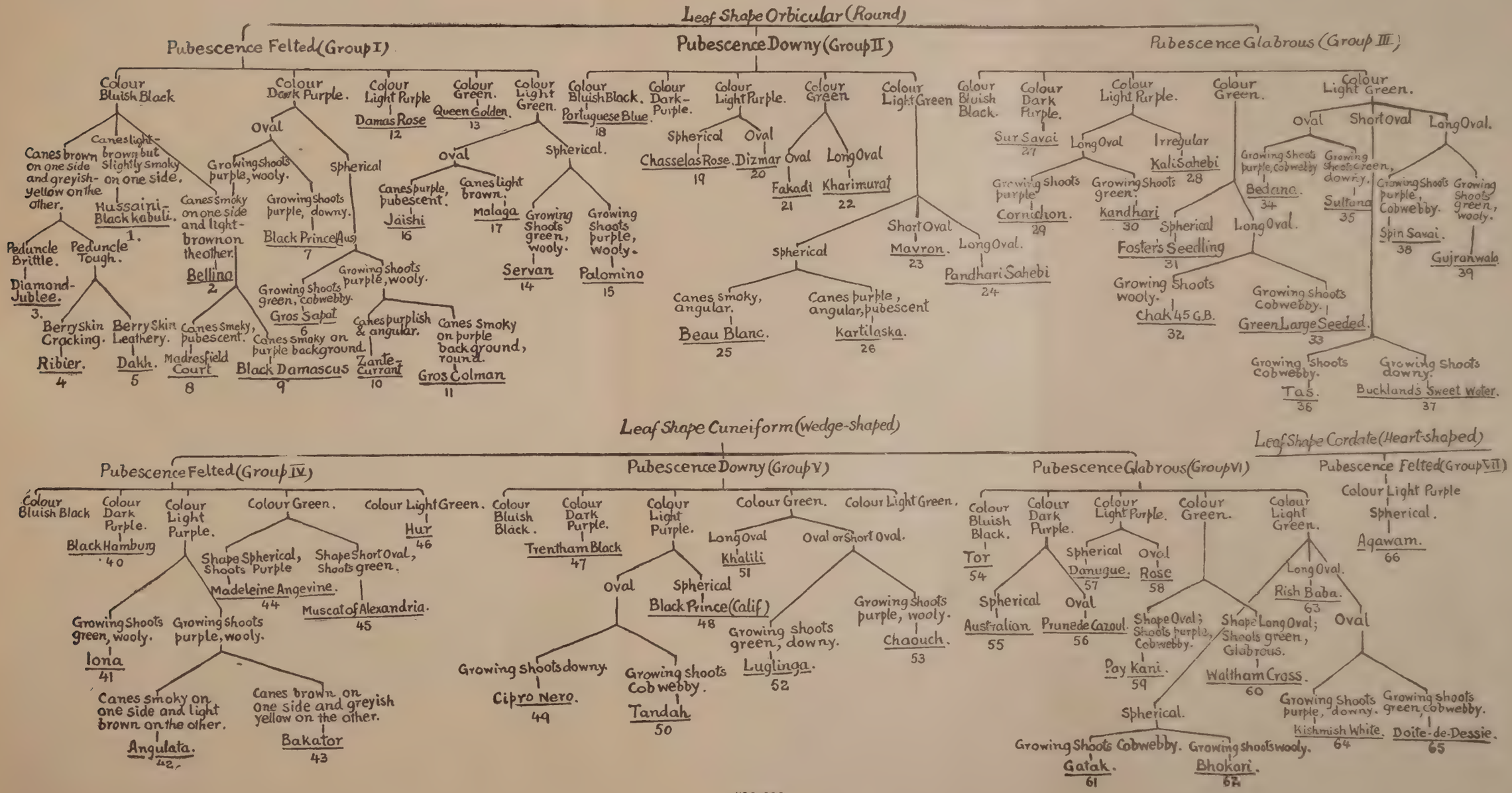
APPENDIX V

Grouping of grape vine varieties with respect to shape of berries

Spherical	Short oval	Oval	Long oval (Ovoid)	Irregular
Agawam	Black Hamburg	Bedana	Cornichon	Kali Sahebi
Angulata	Black Prince	Black Damascus	Chak 45 G. B.	
Australian	Buckland's Sweet Water	Chaouch	Green Large Seeded	
Bakator	Hur	Cipro Nero	Gujranwala	
Beau Blanc	Luglinga	Dizmar	Kandhari	
Bellinc	Malaga	Doite-de-Dessie	Khalili	
Bhokari	Mavron	Fakadi	Kharimurat	
Black Prince (Calif.)	Muscat of Alexandria	Jaishi	Pandhari Sahebi	
Chasselas Rose	Tas	Kishmish White	Rish Baba	
Dakh	Tor	Madresfield-Court	Spin Savai	
Damas Rose	Trentham Black	Pay Kani	Sur Savai	
Danugue		Prunede Cazoul	Waltham Cross	
Diamond Jubilee		Rose		
Foster's Seedling		Sultana		
Gatak		Tandah		
Gros Colman				
Gros Sapat				
Hussaini Black Kabuli				
Iona				
Kartilaska				
Madeleine Angevine				
Palomino				
Portuguese Blue				
Queen Golden				
Ribier				
Servan				
Zante Cu rant				

APPENDIX VI

Showing the Identification of Grape Vine Varieties based on the Shape and Pubescence of Full-grown Leaves, Colour of Berries, Shape of Berries, Colour and Pubescence of Growing Shoots, Cane Characters, and Some Characters of Peduncle, Pedicel and Skin.



A STUDY OF THE PRE-ORCHARD LIFE OF CERTAIN ROOTSTOCKS FOR *CHINEE* ORANGE (*CITRUS SINENSIS* OSBECK) AND ACID LIME (*C. AURANTIFOLIA* (CHRISTM) SWINGLE) AT KODUR

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(Received for publication on 15 September 1939)

(With Plates XVII-XXI and one text-figure)

THAT a proper selection of rootstock for the cultivated citrus plays a most important role in the orchard economics and makes all the difference between the success and failure of a plantation are facts established beyond doubt both by observation and scientific findings. Hatton [1932] has summarized the evidence independently brought out by a number of workers to show the differential performance of certain citrus rootstock-scion combinations under diverse environmental conditions. The wide dissimilarity in the matter of rootstock preferences in the different citrus-growing regions has served to accord a considerable practical and economic importance to the rootstock trials in the research programmes relating to the culture of citrus fruits in all parts of the world.

Until very recently seed propagation has been the rule in citrus nursery practices all over South India. During the past few years there has been, however, a distinct trend towards the establishment of budded plantations. At this stage of transition, questions are being very frequently asked on the merits and demerits of the various rootstocks for the superior cultivated varieties of citrus and also of the several hardy, acclimatised or indigenous forms of citrus that are known to abound in this part of India and are reputed to possess a variety of desirable characteristics like tree vigour, resistence to drought and disease, productivity, tolerance to adverse soil and climatic conditions, etc. Information is also being sought on the possible advantages and disadvantages of raising budded plantations instead of the erstwhile system of seedling plantations.

It was, therefore, in the fitness of things that an elaborate rootstock trial for *chinee* orange and a smaller investigation with acid lime scion variety should find a prominent place in the programme of research under the fruit research scheme of the Imperial Council of Agricultural Research at Kodur. The *chinee* orange is the most extensively cultivated variety of sweet oranges in Ceded districts of Madras Province, almost to the exclusion of other

varieties in this region. Similarly, the acid lime occupies a pre-eminent position among the cultivated fruits that fall under the groups of limes and lemons, in this province as also in other parts of India.

From the very nature of these experiments, it is impossible to expect definite results with any degree of finality within a relatively short period of time. With a crop like citrus, a very conservative estimate of the period necessary to determine with some exactitude the longevity of scions on various rootstocks would be not less than 50 years. Pending the availability of results from such long-range experiments, the citrus growers would naturally welcome the release of practical information on the performance of various rootstocks at different stages of the trial. The information collected so far at the Fruit Research Station, Kodur is considered to be of sufficient interest and practical importance to merit immediate dissemination to the citrus-growing public and to the workers in this field elsewhere. Further results of these trials are proposed to be published as and when they become available and seem sufficiently important from the view point of the practical grower and the research worker on citrus.

Materials

One of the experiments which forms the subject of the present paper was designed to test the relative merits of the following varieties of citrus as rootstocks for *chinee* orange.

(1) *Jamberi—C. limonia* Osbeck. :—This is the well-known rough lemon reputed to be popular as rootstock for sweet orange in some parts of Florida, South Africa, Australia and also in the Central Provinces and Bombay Province. It is said to be identical to *Khatti* of the Punjab and North-West-Frontier and is also known as *jamburi* in some parts of India.

(2) *Kichili—C. maderaspatana* Hort. Tanaka. :—This is indigenous to South India, having probably originated as a chance seedling. Tanaka has described it tentatively in his ' Further Revision of Rutaceae Aurantiodiae of India and Ceylon ' [1937], and concludes that the plant is very much like ' sour orange ' (*C. Aurantium*) with leaves broadly winged. It is undoubtedly a very hardy tree and highly productive in Ceded districts (Plate XVII, fig. 1), where it seems to be resistant to a certain extent to drought, neglect, ill-drained soil conditions and also to such diseases as folio-cellosis, dieback, canker, withertip and gummosis.

(3) *Gajanimma—C. pennivesiculata* Tanaka. :—The description of this has also been recently recorded by Tanaka [1937]. According to him it is identical to Bandhuri of Coorg and Attara of the Central Provinces. This too is possibly indigenous to Ceded districts, having also originated as a chance seedling (Plate XVII, fig. 2). It has been found to be susceptible to gummosis, but in other respects possesses all the desirable characteristics of *kichili* though to a lesser degree. It is known to be a more vigorous grower than *kichili*.

(4) *Gabbu-chinee—C. sinensis* Osbeck. Hort. :—This has arisen as a chance seedling in a *chinee* orange plantation (Plate XVII, fig. 3). Excepting for its producing slightly larger, coarse and more warty fruits, it resembles *chinee* orange morphologically.

FIG. 1

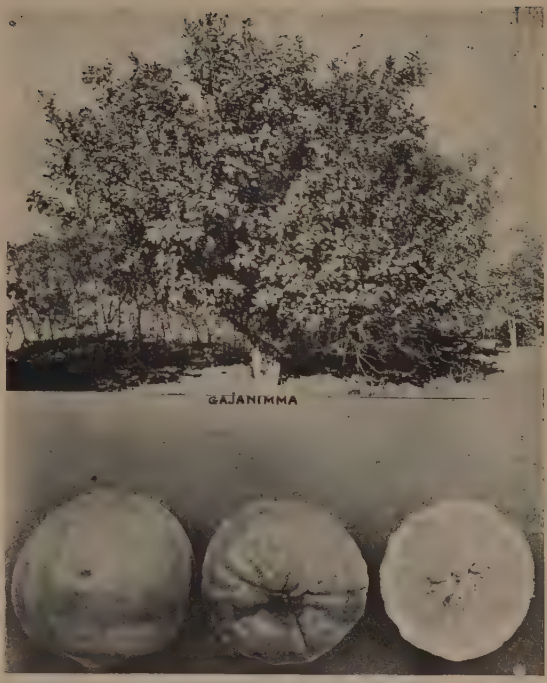

FIG. 2

FIG. 3

FIG. 4

(5) *Chinee* orange—*C. sinensis* Osbeck. :—It is a variety of sweet oranges (Plate XVII, fig. 4), and does not materially differ from any of the well-known varieties known to trade.

(6) *Billi-kichili—C. Tangerina* Hort. *ex* Tanaka. :—This is identical with the tangerine and closely resembles the Dancy and Beauty of Glen-Retreat varieties introduced to India and cultivated in some parts of the United Provinces. It is known also locally as Hyderabad *kamala* and has been considered to be of some value as a rootstock in parts of Florida.

(7) Pummelo—*C. maxima*. Merr. :—The variety used in the present trials bears round fruits. Its value as a rootstock has been tested at Philippines, Florida and in Hawaii [Pope, 1934].

(8) Acid lime—*C. Aurantifolia* Swingle. :—This is the well-known variety of *kaghzi* lime or *nimbu* so extensively cultivated in all parts of India. El Sawy [1936] and Hodgson [1937] have pointed out that a variety of Egyptian limes has been found suitable as a rootstock in light soils.

(9) *Herale—C. Aurantium* Linn. :—According to Tanaka [1937], this is the true sour orange, also known as Seville orange. The seed parent used in these trials appears to be the true Bitter Seville strain, which is used extensively as a rootstock in California. Its fruits do not develop a sweet and edible pulp as those of *kichili*. Tanaka considers *herale* to be synonymous with *shotang* of Assam, *naradabba* of Madras and *khatta* of the Punjab.

A batch of *chinee* seedlings raised from the same scion parent from which buds were obtained for this experiment were also included in these studies, so that their performance may be evaluated with the *chinee* orange scion on each of the above nine varieties employed as rootstocks.

The scion parent chosen for the experiment is tree No. 10 4 in a private garden close to the station.

For the experiment with acid lime scion, the varieties tried as rootstocks were *kichili*, *jamberi* and acid lime. As in the case of the other trial, seedlings raised from the acid lime scion parent were also included in this study. The scion parent for this trial was also selected from a private garden in the neighbourhood.

Along with some of the above citrus, a variety popularly known as Vadlapudi orange (syn. country orange or sour country orange or sour orange) has also been included for a study of root-systems of seedlings and of budlings on the seedling rootstocks. It seems from the descriptions that Tanaka [1937] has taken this variety to be synonymous with the *kichili*, although he has not made a specific statement to that effect. The Vadlapudi orange is being extensively cultivated as a table fruit in the Northern Circars and claims an area of about 4,000 acres, while the *kichili* of the Ceded districts is never grown on a commercial scale and exists merely as stray trees in the sweet orange groves. Pending an accurate nomenclature and classification, which is now in progress at Kodur, these two popularly known varieties are treated as distinct from each other in the present paper, although it must be stated that apparently no clear differences seem to exist between the two.

Mokri, C. medica L., is another variety that was originally included for the rootstock trials, but was ultimately discarded for the purpose. The seed-bed and nursery performance of this variety has, however, been reported in these pages.

Methods

The rootstock trials were initiated towards the close of 1935. The seeds of each variety intended for rootstocks as well as of the scion parents for growing as seedling trees were collected from selected individual trees. The scion parents were chosen with care on the basis of their vigour and performance in the two seasons preceding the bud-insertion. As will be shown hereafter, a very much larger number of seedlings than were actually required for bud-insertion and final planting were raised, so as to permit the selection of rootstocks and scion seedlings with the greatest amount of uniformity of growth characters. This procedure was adopted in consonance with the findings of Webber [1931 ; 1932], who has pointed out the possibility of obtaining a progeny, all individuals of which are likely to be genetically identical, by the process of eliminating the variants among the seedlings. It was not, however, possible to sow uniform number of seeds in the case of every variety.

The seeds of all the varieties were sown towards the close of the year 1935 and the seedlings transplanted in nursery beds from June to September 1936. Data on the percentage of germination, the extent of polyembryony as determined by the counting of the actual number of seedlings produced, and also the extent of variability based on the growth measurements were collected at one or more stages of the growth of the plants in seed and nursery beds.

During the first half of January 1937, a number of vigorous growing variants in nursery beds were utilized for a trial to obtain rough indications of rootstock effects upon the *chinee* scion. Detailed ' take ' of buds on each of these variants were suitably recorded along with the extent of variability of these. The budded plants were transplanted to separate nursery beds during July 1937, at which time the girth records were again collected.

At the time of transplantation of seedlings from seed to nursery beds during July to September 1936, 24 seedlings of eight different varieties were selected for a study of root system. These plants were excavated with considerable care, a trench being dug out on either side and the roots traced as far as practicable to their ultimate tips. The root systems were then drawn and described *in situ*, and were finally reconstructed ; and one specimen from each variety was mounted on cardboards and photographed. The descriptions recorded from these studies along with the data collected on the extent of success in transplantation of seedlings have been utilized to obtain an idea of the possible influence exerted by the various root systems on the life of the plants subsequent to the operation of transplantation from seed to nursery beds.

A separate batch of 96 seedlings of eight different citrus varieties were also planted in September 1936 in a separate plot at a distance of six feet from plant to plant and eight feet from row to row for pursuing the study of roots in later stages of growth. Six seedlings of each of these varieties were budded to a selected *chinee* orange tree in January 1937 and the other six were left to grow as unworked seedlings. One budded plant from each variety along with an unworked seedling of the same variety was lifted every year

during the following three years for a comparative study of the root system as stated above.

The actual budding operation of the finally selected seedling rootstocks for the main experiment both with orange and lime scion was done in July 1937 by one operator. The finally selected budded orange and lime plants were planted out in October, 1938.

The plan of layout of the orange rootstock trial as approved by the Statistician of the Imperial Council of Agricultural Research consists of six replications or blocks for ten treatments. Three trees on each of the nine rootstock varieties and three *chinee* orange seedling trees were planted out in each block, the position of the trees within each of the 60 sub-plots and that of the treatments within each of the six blocks having been determined at random. The plants were planted by the quincunx system with a spacing of about 28 feet from tree to tree.

The soil of this plot was analysed by the Government Agricultural Chemist, Coimbatore ; and on the basis of his report it is found that the soil is red sandy loam of great depth with about 25 per cent of finer fractions in surface layers, and more of clay fractions in the lower strata. The *p*H of the soil is almost neutral in reaction, being 7·5. The total water-soluble salts are very low with no difference between the surface and sub-layers. The water-holding capacity and the pore space are also uniformly fair. The area is, therefore, considered to provide ideal plots for this type of experimentation.

In the case of acid lime trial, the plan of layout consists of six replications of four treatments (budlings on three rootstock varieties and acid lime seedlings). The spacing adopted in this case was 20 feet square. The soil analysis of the plot reserved for this trial shows that this plot is identical with that used for the orange rootstock trials.

At the time of planting the trees in both the experiments measurements of trunk thickness of the rootstock stem and scion stem and of the height of the plants were collected and recorded. Once a year such records are proposed to be collected in future so as to trace the differential growth effects under each of the treatments. In the present paper, the data relating to the series of measurements collected in the orchard immediately after planting are only discussed along with those collected prior to the planting.

Data and inferences

1. Chinee *orange rootstock trial*

In Table I are presented the data collected on germination and ploymbryony, etc. in seed beds and growth and variability in nursery beds, in the case of various rootstock varieties for *chinee* orange.

Table I shows that wide differences exist between the various varieties particularly with regard to the growth prior to the budding stage. Clear differences are also observed in regard to the phenomenon of ploymbryony as determined on seedling counts, and percentage of germination.

TABLE I

Summarized growth record and other observations on seedlings

(*Rootstock trial for* chinee *orange*)

Serial No.	Variety of root-stock	Ger-mina-tion	Time taken for ger-mina-tion in days	Seed-lings from apogamic embryos *	Buddable plants with a diameter of 0·70 cm. or above, at 9" height on 7-11-36	Aver-age height in Nov-ember, 1936	Coeffi-cient of varia-bility	Average diameter at 12 cm. height in Novem-ber, 1936	Coeffi-cient of varia-bility
		Per cent		Per cent *	Per cent	cm.	Per cent	cm.	Per cent
1	2	3	4	5	6	7	8	9	10
1	Sweet orange (*Chinee*)	43·00	20	...	...	38·80	20·00± 0·87	0·33	32·83± 0·01
2	*Kichili*	78·37	15	57·00	6·0	55·80	24·55± 0·25	0·50	21·80± 0·01
3	*Gajanimma*	62·80	19	65·10	59·0	60·80	20·25± 0·84	0·74	25·68± 0·01
4	*Gabbu chinee*	80·00	17	4·30	2·0	43·60	26·61± 0·78	0·42	24·88± 0·01
5	*Jamberi*	99·10	20	73·40	53·0	62·00	23·06± 0·95	0·68	27·20± 0·01
6	*Billi-kichili*	85·20	24	16·50	...	34·90	34·41± 0·84	0·34	29·11± 0·01
7	Pummelo	91·00	17	...	12·0	36·80	36·28± 1·44	0·50	28·00± 0·01
8	Acid lime	80·00	20	38·66	3·0	54·60	22·43± 0·83	0·45	26·22± 0·01
9	*Herale*	50·00	(*)	2·05	(*)	(*)	(*)	(*)	(*)
10	*Chinee* (unbudded)	62·00	20	...	...	19·10	16·39± 0·43	0·21	31·43± 0·01
11	*Mokri*	82·00	20	...	31·9	36·10	27·53± 0·98	0·53	35·28± 0·02

NOTE :—Chinee under item No. 1 is from a parent different from that mentioned under item No. 10.

*Calculated on the basis of actual number of seedlings obtained from 100 seeds.

(*) Records not available.

In regard to the growth in the nursery, the data indicate that *jamberi* and *gajanimma* make the most vigorous growth during the first year. It is also seen that height measurements do not afford any uniformly reliable indication of the suitability of the seedlings to receive buds.

The data relating to seedlings from two different parents of *chinee* appear to disclose the fact that the rate of growth is a factor which is largely influenced by the individual parent in this variety.

The data collected on percentage ' take ' of buds on vigorous growing variants and also on the variability among these seedlings are presented in Table II.

TABLE II

Data on percentage ' take ' and growth of seedling variants as well as on variability among such seedlings at the time of budding

(*Rootstock trial for* chinee *orange*)

Serial No.	Rootstock variety	No. of variants budded	Date of budding	Percentage ' take '	Average diameter of rootstock at the time of budding at 3 in. height (cm.)	Coefficient of variability of seedlings at the time of budding Per cent
1	Sweet orange	...	...	...	...	...
2	*Kichili*	54	7-1-37	87·30	0·88	10·51±0·01
3	*Gajanimma*	53	9-1-37	77·36	1·19	13·45±0·01
4	*Gabbu-chinee*	79	3-1-37	55·70	0·71	12·52±0·01
5	*Jamberi*	50	5-1-37	86·00	1·28	10·02±0·01
6	*Billi-kichili*	6	9-1-37	100·00	0·66	9·09±0·05
7	Pummelo	16	10-1-37	56·25	0·84	12·55±0·02
8	Acid lime	25	Do.	80·00	0·79	11·40±0·01
9	*Mokri*	23	Do.	69·57	0·86	12·56±0 02

Although the number of individuals worked were limited, and varied between varieties, the data in Table II nevertheless point out to the existence of fairly large differences between the several rootstock varieties in regard to the successful ' take ' of *chinee* orange buds.

The data also show that the coefficient of variability in stem size of the variants is considerably less than what was found in the seedlings of the respective varieties two months before. This leads to the hope that the final set of seedlings selected for raising the experimental plants will be fairly uniform at least in so far as the measurements of stem thickness are concerned.

The preceding observations, however, require to be confirmed. This was done at the time of working the seedlings selected finally as the least variable in each rootstock variety.

Table III shows the mean increase in rootstock stem girth of the variants till the time of transplantation of budded plants to fresh nursery beds in July 1937.

TABLE III

Number of budded plants on most vigorous variant rootstocks and their mean growth increments till the time of their second transplantation in nursery beds

(*Rootstock trial for* chinee *orange*)

Serial No.	Rootstock variety	No. of plants	Mean increase in stem diameter cm.
1	Sweet orange	*Nil*	*Nil*
2	*Kichili*	34	0·308±0·045
3	*Gajanimma*	25	0·256±0·041
4	*Gabbu-chinee*	24	0·224±0·043
5	*Jamberi*	17	0·258±0·073
6	*Billi-kichili*	5	0·157
7	*Pummelo*	3	0·084
8	Acid lime	13	0·159±0·077
9	*Mokri*	6	0·183

The number of plants in pummeloes, *billi-kichili* and *mokri* is too few to be included for statistical test. In respect of other rootstock varieties, it is found that *kichili* has shown the largest rate of increase while *jamberi*, *gajanimma* and *gabbu-chinee* follow in the order in which they are given here.

In the following June 1937 when the measurements of trunk thickness of the unworked seedlings were collected, attempt was made to determine the extent of uniformity of these seedlings. The data are graphically represented in Fig. 1, which shows the frequency diagram and illustrates the distribution of trunk thickness of the seedlings of five of the rootstock varieties which had a large population in each. Of the five curves, *jamberi* alone gives a nearly normal curve with B2=2·9602, and B1=0·0813, but the theoretical curve does not give a good fit to observation. In other cases the curves approximate to Pearson's type I, but do not give a good fit to observed data, especially in the case of *gabbu-chinee*. The standard deviations range from 0·83 cm. in acid lime to 1·23 in *gabbu-chinee*.

Due to the high variability of the samples and in order to get uniformity in the materials, selections were made from the modal class only in the case of five rootstock varieties for budding. In other four varieties it was not possible to select individuals from modal class owing to the limited number of seedlings present. Table IV represents the number of individuals falling in the modal class and their trunk thickness.

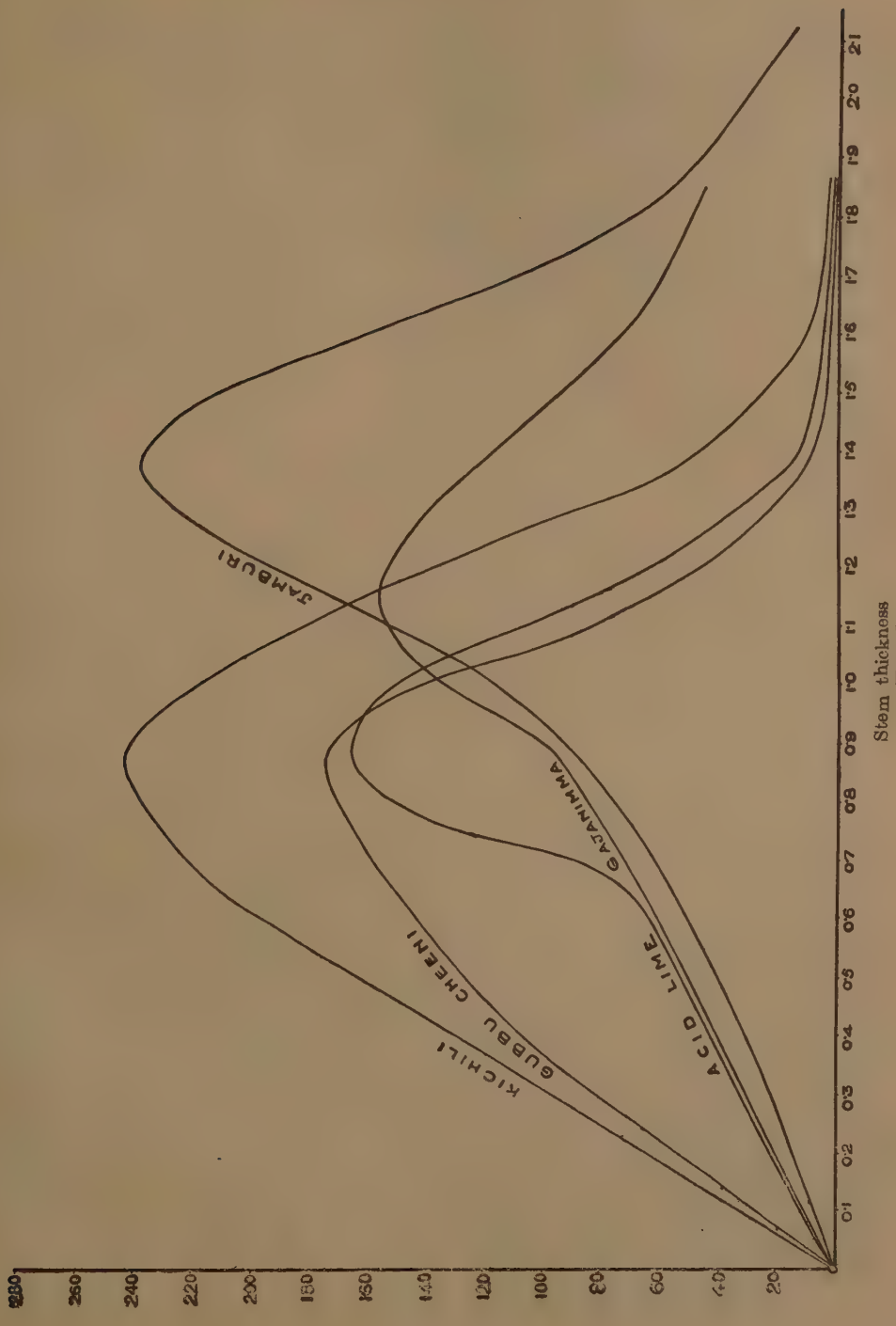
JAMBURI
KICHILI
GUBBU CHEENI
ACID LIME
GATANIMMA
Stem thickness
0·1 0·2 0·3 0·4 0·5 0·6 0·7 0·8 0·9 1·0 1·1 1·2 1·3 1·4 1·5 1·6 1·7 1·8 1·9 2·0 2·1
20 40 60 80 100 120 140 160 180 200 220 240 260 280

FIG. 1

TABLE IV

Number and proportion of seedlings in the modal class with central values and mean diameter measurements of different rootstocks

(*Rootstock trial for* chinee *orange*)

Rootstock variety	No. of individuals in modal class	Percentage of seedlings in modal class	Central value—diameter cm.	Mean value—diameter cm.
Jamberi	139	39·95	4·321	4·369
Kichili	228	39·72	2·750	2·797
Gajanimma	98	25·32	4·321	4·325
Gabbu-chinee	123	31·87	2·750	2·775
Acid lime	120	46·51	2·750	2·791

It is seen that *jamberi* and *gajanimma* have shown a greater stem thickness in the modal class than the seedlings of the other three varieties.

At the time of transplantation of seedlings from seed to the nursery beds, all the undersized and weak seedlings were rogued out once, and the rest were graded into three groups according to the size of the plants, and seedlings of each of these three grades were planted in separate but contiguous nursery beds.

Table V gives an idea of the extent of roguing out performed, number of plants falling under each grade and the significance of difference between the seedlings of each of these grades based on their stem girth measurement at the time of budding in July 1937.

It is evident from Table V that there is no significant difference between any of the grades in *gabbu-chinee*, *gajanimma* and acid lime, which therefore appear to be the least variable of all the five rootstocks. *Kichili*, on the other hand, appears to be most variable because of the significant difference between the A and B grades, and A and C grades.

In view of the repeated roguing out of the undersized and weak plants and of variants in seed and nursery beds respectively, and the further precaution taken in selecting only the individuals from the modal class in five varieties, no further steps appeared necessary for having the most uniform seedling rootstocks for the purpose of this trial. Nevertheless, as the number of individuals in the modal class of some of the varieties was large, it was found necessary to make a further selection of individuals out of those finally selected groups, so as to restrict the budding operation to a conveniently manageable number. Unfortunately, a uniform number of plants could not be obtained in the case of all rootstock varieties, mainly because of the inadequate number of plants raised in their case.

TABLE V

Extent of roguing out and proportion of seedlings under each grade of rootstocks with a comparison of their mean stem diameter measurements

(*Rootstock trial for* chinee *orange*)

Rootstock variety	Total No. of seedlings raised	Per cent rogued out	Percentage under each grade			Mean stem diameter at the time of budding			Significance of difference in respect of thickness between seedlings of		
			Height above 55 cm. A	Height between 26 & 55 cm. B	Height below 26 cm. C	A grade cm.	B grade cm.	C grade cm.	A & B	B & C	A & C
Jamberi	969	23·84	5·58	38·39	32·19	1·655	1·465	1·188	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not signi-ficant.	$P < \cdot 05$ signi-ficant but barely so.
Kichili	1,164	36·60	5·15	52·06	6·19	1·141	0·83	0·570	$P < \cdot 05$ signi-ficant.	$P > \cdot 05$ not signi-ficant.	$P < \cdot 05$ signi-ficant.
Gajanimma	1,008	43·34	8·35	41·17	7·14	1·323	1·232	0·956	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not singi-ficant.
Gabbu-chinee	1,143	35·42	1·57	46·20	16·80	0·886	0·768	0·688	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not signi-ficant.
Acid lime	510	14·51	10·20	61·17	14·12	0·951	0·949	0·783	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not signi-ficant.	$P > \cdot 05$ not signi-ficant.

In Table VI are presented the number of individuals finally budded, their mean girth, the coefficient of variability and the percentage 'take'. The budding was done by one operator with scions obtained from a single *chinee* orange tree from 4th to 12th July 1937.

TABLE VI

Percentage 'take' and mean stem diameter and variability at the time of budding chinee *on nine rootstocks*

(*Rootstock trial for* chinee *orange*)

Serial No.	Rootstock variety	Number budded	Date of budding	Percentgae 'take'	Average stem diameter at the time of budding (cm.)	Coefficient of variability per cent
1	*Chinee*	24	12-7-37	95·83	2·48	18·43
2	*Kichili*	50	7-7-37	88·00	2·66	5·00
3	*Gajanimmd*	50	9-7-37	90·00	4·24	3·12
4	*Gabbu-chinee*	50	9-7-37	64·00	2·80	7·87
5	*Jamberi*	51	4-7-37	92·00	4·27	3·65
6	*Billi-kichili*	35	11-7-37	62·25	2·58	7·62
7	Pummelo	28	12-7-37	96·46	2·99	17.90
8	Acid lime	35	11-7-37	97·14	2·80	9·42
9	*Mokri*	30	12-7-37	96·67	2·92	23·63

The afore-mentioned data denote that the 'take' is very high on all varieties except on *gabbu-chinee* and *billi-kichili*.

Jamberi and *gajanimma* seedlings appear to have produced the most vigorous seedlings at the time of budding, while *chinee*, *billi-kichili* and *kichili* have produced the least vigorous individuals.

It has been pointed out in the previous pages that the selection of the plants in the nursery beds leads to considerable narrowing down of the coefficient of variability. The figures in Table VI further substantiate this hypothesis, as except in *chinee*, pummelo and *mokri*, which contain a few individuals under each, the coefficient of variability has been reduced considerably by the repeated roguing out of the variants.

The finally selected budded plants of *chinee* orange on nine different rootstocks and seedlings of the same scion parent were planted out in their permanent orchard sites in October 1938. As stated already, *mokri* was replaced by *herale*, because of the availability of an insufficient number of uniform budded plants on the former rootstock at the time of planting. The latter rootstock was also raised almost at the same time and under similar conditions as those of the other eight rootstock varieties included in this trial.

The details of the experiment and materials, other than those referred to in the foregoing pages, are given in Table VII, while the analysis of the measurements of trunk thickness of all the plants at the time of planting and of the diameter and height increments from the time of budding to the time of final planting in the orchard are presented in Tables VIII-XI. In

TABLE VII

Some of the details of the trial with rootstocks for chinee *orange and of the materials used in the study*

(*Trial with rootstocks for* chinee *orange*)

1. Plot size . . . . . 120 ft. × 120 ft. (0·055 acre)
2. Number of plants in each plot . . . 3
3. Spacing . . . . . 28·28 feet (40 feet quincunx)
4. Number of replications 6
5. Scion tree used . . . . . *Chinee* (sweet orange), tree No. 10/4 in B. J. Garden at Kodur.
6. Performance of scion parent . . . .

	Yield :—No. of fruits		
Year	Angam	Gairangam	Total
1935-36	950	50	1,000
1936-37	825	10	835

Name of rootstock	Key to treatment	Date of sowing	Date of primary transplantation	Extent of roguing in nursery beds *	Date of second transplantation	Date of final planting
Jamberi	A	12-11-35	25-6-36	40·00	6-6-38	10th to 13th October 1938
Gajanimma	B	17-11-35	30-6-36	40·00	8-6-38	Do.
Kichili	C	Do.	27-6-36	40·00	7-6-38	Do.
Billi-kichili	D	19-11-35	8-7-36	35·71	10-6-38	Do.
Gabbu-chinee	E	24-10-35	3-7-36	40·00	9-6-38	Do.
Pummelo	F	17-12-35	9-7-36	40·00	11-6-38	Do.
Herale	G	7-2-36	30-6-36	34·48	12-6-38	Do.
Acid lime	H	23-11-35	7-7-36	25·00	10-6-38	Do.
Chinee	I	Do.	18-9-36	40·00	11-6-38	Do.
Chinee seedling	J	27-12-35	Do.	25·00	15-6-38	Do.

* Extent of roguing in seed beds has been given in Table V.

TABLE VIII

Summary of results regarding the diameter measurements of rootstock stems at the time of final planting
(Orange rootstock trial)

—	A	B	C	D	E	F	G	H	I	J	General mean	S. E. D. M.	Level of significance	Critical difference
Mean diameter per treatment in cm.	1·69	1·64	1·19	1·00	1·22	1·30	1·29	1·10	1·10	0·98	1·25	0·06	$P=0·05$	0·12
													$P=0·01$	0·16
Mean diameter as percentage of general mean	135·20	131·20	95·19	80·00	97·61	104·00	103·20	88·00	88·00	78·39	100·00	4·80	$P=0·05$	9·60
													$P=0·01$	12·80

Conclusion—

At 5 per cent level of significance :— A B F G E C I H D J

(Treatments under or above the same bar do not differ significantly from each other)

TABLE IX

Summary of results regarding the diameter measurements of scion stems at the time of final planting
(Orange rootstock trial)

—	A	B	C	D	E	F	G	H	I	J	General mean	S. E. D. M.	Level of significance	Critical difference
Mean diameter of scion in cm.	1·22	0·95	0·77	0·61	0·84	0·60	0·79	0·51	0·72	0·98	0·80	0·05	$P=0·05$	0·11
													$P=0·01$	0·14
Mean diameter as percentage of general mean	152·50	118·80	96·25	76·25	105·00	75·01	98·74	63·75	89·99	122·50	100·00	6·87	$P=0·05$	13·75
													$P=0·01$	17·50

Conclusion—

At 5 per cent level of significance :— A J B E G C I D F H

(Treatments under or above the same bar do not differ significantly from each other)

TABLE X

Results regarding the height measurements of chinee *orange rootstock varieties and of* chinee *orange seedlings at the time of final planting*

(*Orange rootstock trial*)

——	A	B	C	D	E	F	G	H	I	J	General mean	S. E. D. M.	Level of significance	Critical difference
Mean height in cm.	56·70	43·17	35·28	28·34	43·14	29·56	40·25	25·72	35·97	42·08	38·02	3·33	$P=0·05$	6·53
													$P=0·01$	8·57
Mean height as percentage of general mean.	149·10	113·60	92·79	75·54	113·40	77·75	105·90	67·64	94·62	110·70	100·00	8·76	$P=0·05$	17·18
													$P=0·01$	22·54

Conclusion—

At 5 per cent level of significance :— A B E J G I C F D H

(Treatments under or above the same bar do not differ significantly from each other)

TABLE XI

Results regarding the increase in diameter of the rootstock and seedling stems from the time of budding till final planting

(*Orange rootstock trial*)

——	A	B	C	D	E	F	G	H	I	J	General mean	S. E. D. M.	Level of significance	Critical difference
Mean increase in diameter per treatment in cm.	0·37	0·31	0·33	0·17	0·33	0·19	0·08	0·17	0·35	0·75	0·30	0·05	$P=0·05$	0·11
													$P=0·01$	0·14
Mean increase in diameter as percentage of general mean	123·30	104·00	110·00	56·66	110·00	63·34	26·67	56·66	116·70	250·00	100·00	16·67	$P=0·05$	36·67
													$P=0·01$	46·67

Conclusion—

At 5 per cent level of significance :— J A I C E B F D H G

(Treatments under or above the same bar do not differ significantly from each other)

TABLE XII

Rootstock trial for acid limes

Rootstock variety	Germination	Time taken for germination in days	Per cent of seedlings from apogamic embryos, (calculated on 100 seeds)	Per cent of buddable plants available on 17th November 1936 (0·70 cm. and above)	Height measurements taken during November 1936		Diameter of stem during November 1936 (12 cm. ht.)	
					Average height	Coefficient of variability	Average diameter	Coefficient of variability
	per cent				cm.	per cent	cm.	per cent
1 *Kichili*	78·37	15	57·00	6·0	58·8	24·55±0·25	0·50	21·8 ±0·01
2 *Gajanimma*	63·00	19	23·00	22·0	47·9	29·65±0·96	0·56	28·57±0·01
3 *Jamberi*	79·00	18	29·00	94·0	61·9	25·31±1·32	0·68	25·00±0·01
4 *Gabbu-chinee*	70·00	17	2·07	..	44·0	27·09±0·80	0·41	23·41±0·01
5 Acid lime	80·00	20	38·66	3·0	54·6	22·43±0·83	0·45	26·22±0·01
6 Acid lime (unbudded)	80·00	20	38·66	3·0	54·6	22·43±0·83	0·45	26·22±0·01

NOTE.—Excepting in the case of *kichili* and acid lime, the seedlings raised for this trial are from parents which are different from those selected for rootstock trials for *chinee* orange.

the case of diameter measurements of budlings at the time of planting, the data have been collected at two different places, one around the rootstock stem at one inch below the bud-joint and another around the scion shoot one inch above the bud-union.

It is evident from these data that among the budded plants, *jamberi* is the most outstanding of all the rootstocks, since it has not only registered the highest increase in diameter of rootstock and scion stems but also has produced the largest sized plants at the time of final planting. Though *chinee* seedlings had a relatively poor stem thickness in comparison with other rootstocks at the commencement of their orchard life, they had recorded the largest trunk thickness increments during the preceding year. The latter feature can only be explained by the fact that the retarding influence of budding on growth was non-operating in its case.

Billi-kichili, acid lime, *chinee* and pummelo have produced the lowest sized plants at the time of planting, but trees on *chinee* rootstock had however registered very large growth increments during the preceding year to an extent comparable to the plants on *jamberi*. In respect of the size of the rootstock stems at the time of planting, *chinee* on *gajanimma* is almost on a par with that on *jamberi*.

2. Lime rootstock trial

In Table XII are given the data collected in seedbeds on seedlings of rootstocks raised for this trial.

The percentage ' take ' obtained by budding the variants during the third week of January, as well as the measure of variability in terms of rootstock stem diameter are given in Table XIII.

TABLE XIII

Percentage ' take ' of acid lime scion on some roostock variants with the rootstock size and variability

Rootstock variety	No. of variants budded	Date of budding	Percentage ' take '	Average diameter of stock at the time of budding 3 in height (cm.)	Coefficient of variability per cent
1 *Kichili*	52	18-1-37	11·54	0·75	11·20
2 *Gajanimma*	50	20-1-37	64·00	1·01	13·07
3 *Jamberi*	50	22-1-37	60·00	1·11	13·97
4 *Gabbu-chinee*	51	16-1-37	17·65	0·78	10·27
5 Acid lime	26	21-1-37	11·54	0·81	11·58

It is observed that all the five rootstock varieties have given a lower percentage ' take ' with acid lime scions than with scions of *chinee* orange. This variation is particularly noticeable on *kichili*, *gabbu-chinee* and acid lime. It has also been observed that the period taken for the acid lime buds to sprout was markedly greater than that taken by *chinee* buds on similar rootstock varieties. These observations appear to point out to the existence of differential extent of congeniality in the different combinations of rootstock and scion varieties ; or in other words, different scion varieties appear to respond differently on a given rootstock variety.

As in the rootstock trial for *chinee* orange, the extent of variability in the variant seedlings of all the rootstock varieties have been considerably narrowed down as a result of selection.

The number of vigorous growing seedling variants selected for budding in this experiment was limited, and except in the case of *jamberi* and *gajanimma*, the stem diameter records have not been collected as in the case of orange scion. The number of the budded variants on *gajanimma* was 17 and on *jamberi* 16, and the increase in stem diameter from the date of bud-insertion on 20th January 1937 to the date of primary transplantation on 16th July 1937 was 0·88 cm. and 0·82 cm. respectively.

The number of individuals in the modal class of each of these rootstock varieties along with their central values are given in Table XIV.

TABLE XIV

Proportion of seedlings in the modal class with mean and central stem diameter value

(*Rootstock trial for acid limes*)

Serial No.	Rootstock variety	No. of individuals in the modal class	Percentage of seedlings in the modal class	Central value diameter cm.	Mean value diameter cm.
1	*Kichili*	228	39·72	2·75	2·797
2	*Gajanimma*	83*	..	..	3·583
3	*Jamberi*	84*	..	..	2·274
4	*Gabbu-chinee*	114	36·30	2·75	2·816
5	Acid lime	120	46·51	2·75	2·766

* Due to limited number of individuals, the seedlings having the narrowest range of variation were selected in these varieties.

Table XV shows the final number of individuals budded to acid lime, their mean stem diameter, coefficient of variability and the percentage ' take '. In this case too, the budding was done by one and the same operator as in orange rootstock trial.

TABLE XV

Percentage 'take' with acid lime scion and average stem diameter and variability of rootstocks

Serial No.	Rootstock variety	Number budded	Date of budding	Percentage 'take'	Average diameter at the time of budding in cm.	Coefficient of variability percentage
1	*Kichili*	50	16-7-37	18·0	2·76	9·40
2	*Gajanimma*	50	18-7-37	50·0	3·68	4·84
3	*Jamberi*	57	15-7-37	42·0	4·35	18·00
4	*Gabbu-chinee*	50	19-7-37	16·0	2·62	8·68
5	Acid lime	35	14-7-37	80·8	2·86	11·60

Due to the limited number of budded individuals on *kichili* and *gabbu-chinee*, these two rootstock varieties had to be left out of the trial. Uniform and healthy budlings of acid lime on the remaining three rootstocks, viz. *jamberi*, *gajanimma* and acid lime, and seedlings of the same scion parent were finally selected and planted out in their permanent orchard sites in October 1938 according to the layout described already.

Details of the plant material used, key to treatments, etc. are furnished in Table XVI.

TABLE XVI

Key to treatment, details of plant material used, layout, etc.

(*Rootstock trial for acid limes*)

1. Plot size — 60 ft. × 20 ft. (0·0275 acre)
2. Number of replications — 6
3. Number of trees in each plot — 3
4. Spacing — 20 feet (square).
5. Scion material used — Acid lime; tree No. 4/6, N. K. Garden, Kodur
6. Scion performance

Yield	Number of fruits
1935-36	2,000
1936-37	2,500

7. Date of planting — 20th to 21st October 1938.

Rootstock variety	Key to treatments	Date of sowing	Extent of roguing out in seed-beds (per cent)	Date of primary transplantation	Extent of roguing out in nursery beds (per cent)	Date of budding	Date of second transplantation
Jamberi . .	A	19-12-35	*Nil*	3-7-36	40·00	15-7-37	13-6-38
Gajanimma .	B	18-11-35	52·50	1-7-36	40·00	18-7-37	14-6-38
Acid lime . .	C	23-11-35	14·50	7-7-36	40·00	14-7-37	14-6-38
Acid lime (seedling)	D	23-11-35	14·50	7-7-36	40·00	...	15-6-38

TABLE XVII

Summary of results regarding the diameter measurements of rootstock stems and of stems of seedling trees at the time of final planting

(*Acid lime rootstock trial*)

	A	B	C	D	General mean	S. E. D. M.	Level of significance	Critical difference
Mean diameter per treatment in cm.	1·95	1·56	1·22	1·49	1·55	0·06	$P=0·05$ $P=0·01$	0·12 0·17
Mean diameter as per cent of the general mean	125·80	100·70	78·72	96·14	100·00	3·87	$P=0·05$ $P=0·01$	7·74 10·96

Conclusion.—At 5 per cent level of significance :—A $\overline{\text{B D}}$ C
(Treatments under the same bar do not differ significantly from each other)

TABLE XVIII

Summary of results regarding the scion stem diameter at the time of final planting

(*Acid lime rootstock trial*)

	A	B	C	D	General mean	S. E. D. M.	Level of significance	Critical difference
Mean diameter in cm.	1·42	0·92	0·71	1·48	1·13	0·08	$P=0·05$ $P=0·01$	0·16 0·23
Mean diameter as per cent of general mean	125·70	81·41	62·84	131·00	100·00	7·08	$P=0·05$ $P=0·01$	14·16 20·35

Conclusion.—At 5 per cent level of significance :—$\overline{\text{D A}}$ B C
(Treatments under the same bar do not differ significantly from each other)

TABLE XIX

Summary of results regarding height measurements of the plants at the time of final planting
(Acid lime rootstock trial)

	A	B	C	D	General mean	S. E. D. M.	Level of significance	Critical difference
Mean height in cm. . .	84·67	55·00	43·50	73·22	64·10	6·96	$P=0·05$ $P=0·01$	14·84 20·51
Mean height of the plants as per cent of general mean	132·10	85·80	67·85	114·20	100·00	10·86	$P=0·05$ $P=0·01$	23·15 32·00

Conclusion.—At 5 per cent level of significance :—$\overline{A \quad D}$ $\quad$ $\overline{B \quad C}$
(Treatments under the same bar do not differ significantly from each other)

TABLE XX

Summary of results regarding the increase in stem thickness of the various rootstocks from the time of budding till final planting

(Acid lime rootstock trial)

	A	B	C	D	General mean	S. E. D. M.	Level of significance	Critical difference
Mean increase in diameter in cm.	0·53	0·36	0·25	0·52	0·41	0·09	$P=0·05$ $P=0·01$	0·19 0·27
Mean increase in diameter as per cent of general mean	129·30	87·80	60·96	126·90	100·00	21·95	$P=0·05$ $P=0·01$	46·34 65·86

Conclusion.—At 5 per cent level of significance :—$\overline{A \quad D \quad B \quad C}$
(Treatments under the same bar do not differ significantly from each other)

As in the *chinee* orange rootstock trial, stem diameter and height measurements of the plants collected at the time of final planting and the stem diameter increments from the time of budding to that of final planting have been analysed, and these are set forth in Tables XVII—XX.

These various data make it clear that *jamberi* has produced the largest rootstock stem thickness at the time of planting, while acid lime rootstock has produced the least. During the pre-orchard life also the latter has produced the smallest growth increments in regard to rootstock stems, but no significant difference is evident between it and *gajanimma* rootstock. With regard to the stem thickness of the seedlings and the scions, it is found that *jamberi* and acid lime seedlings have produced the largest increments at the time of final planting whereas the plants on acid lime and *gajanimma* rootstocks have occupied the lowest ranks.

3. Citrus root studies

The data and observations collected from root excavations carried out during 1936-37 are given in Table XXI.

It is seen from the data presented herein that a collection of seedlings of any of the varieties include plants of differing root habit.

In spite of this range of variation, certain specific or varietal characters are indicated from these data especially in regard to depth of root, the quantity and distribution of fibrous and lateral roots, extent of branching of roots and the stem : root ratio. From these preliminary studies, the following different types of root systems appear to be associated with different varieties :—

Kichili :—Stout but comparatively short laterals ; deeply anchored. Branching of roots mainly towards the extremities of the main tap-roots. Sparsely fibred in the upper soil layers but moderately fibrous towards the lower ends. Appears to make relatively dwarf plants in the nursery in proportion to depth of roots.

Gajanimma :—Very stout tap-root and few laterals on the upper layers, but these are well distributed. Noticeably free in sending out new adventitious roots. Fairly abundant and well distributed fibre throughout the root system. Deep rooted.

Jamberi :—Abundance of coarse and spreading laterals, with a good amount of well distributed fibre. Stout and deeply anchored tap-root. Spread of laterals more marked than in *gajanimma* and *kichili* and with more abundant fibre, a good proportion of which is confined to surface.

Pummelo :—A compact root system with many strong and spreading laterals. Well fibred. Has a short but stout tap-root. Appears to have a tendency to grow somewhat horizontally in the upper layers of soil. Makes the largest top growth in nursery in proportion to root depth among all the varieties.

Acid lime :—Medium to small root system. Fibre sparse except towards the extremities, where coarse laterals are fairly well supplied with fibre. Tap-root thin.

FIG. 1

FIG. 2

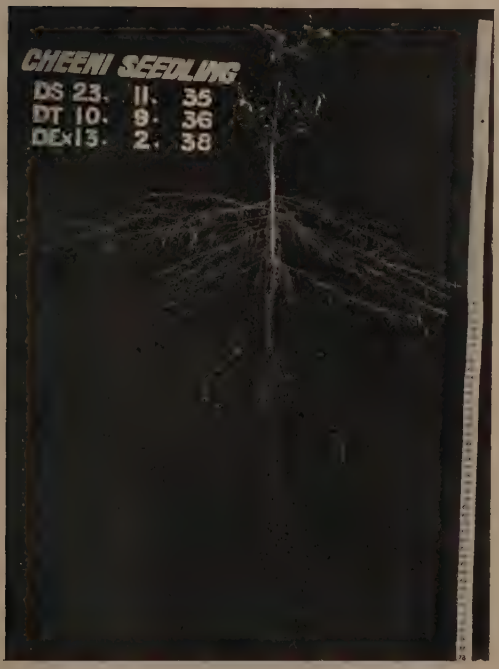

FIG. 3

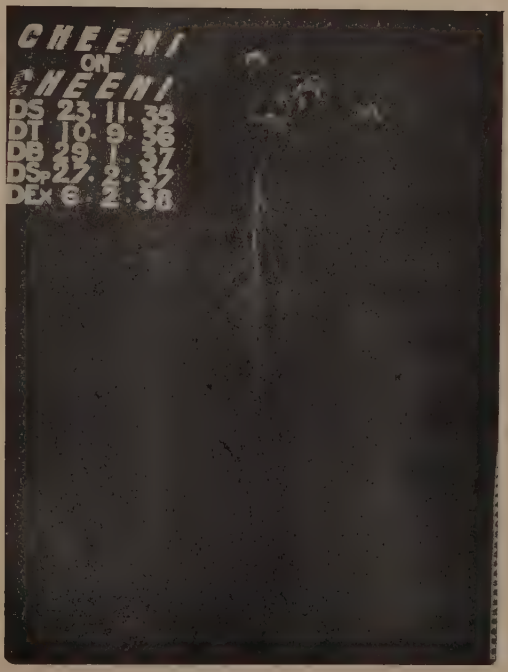

FIG. 4

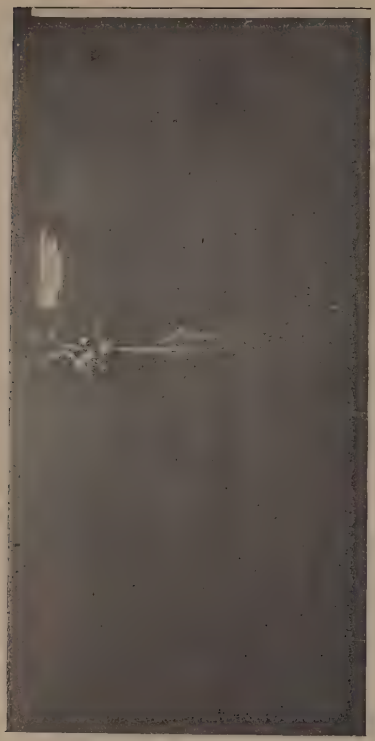

FIG. 2

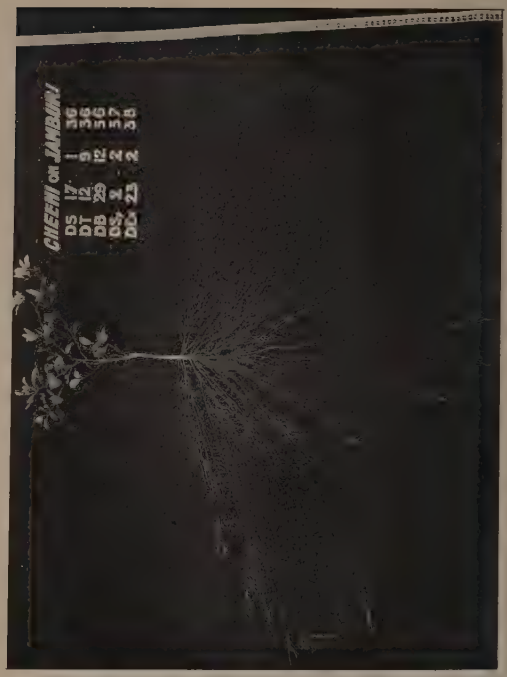

FIG. 4

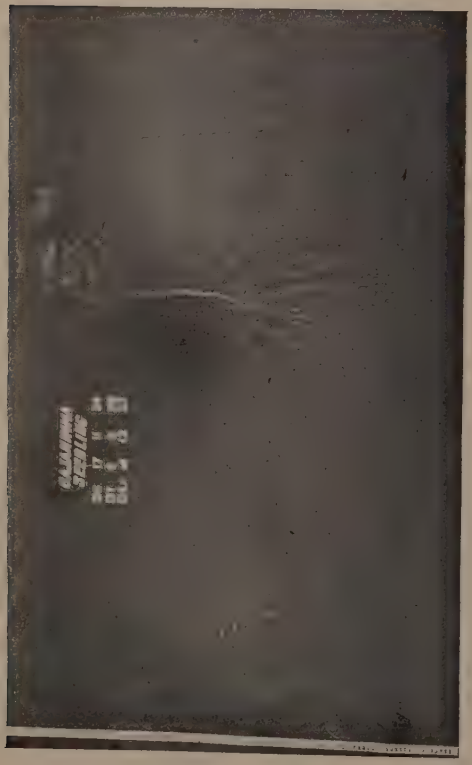

FIG. 1

FIG. 3

TABLE XXI

Records on root system of citrus seedlings (1936-37)

No.	Variety	Age of seedling on the day of study	Depth of root cm.	Greatest length of laterals cm.	Shoot wt. / Root wt. Ratio	Ht. of shoot / Root length Ratio	Number of laterals: Up to 3 in.	Between 3 in. and 6 in.	Between 6 in. and 9 in.
		M. Days							
1	*Kichili*	(*a*) 8 19	115·0	16·0	1·08	0·27	16	19	20
		(*b*) 8 19	121·0	18·0	1·07	0·28	16	24	27
		(*c*) 8 19	126·0	10·1	1·11	0·30	20	26	27
2	*Gajaninma*	(*a*) 6 18	137·0	40·0	1·46	0·39	6	25	10
		(*b*) 6 18	111·0	31·0	0·76	0·37	6	14	10
		(*c*) 6 18	110·0	25·0	0·43	0·27	14	20	12
3	*Jamberi*	(*a*) 8 6	111·5	45·1	1·07	0·62	28	39	42
		(*b*) 8 6	107·5	41·0	1·17	0·58	18	28	26
		(*c*) 8 6	102·5	45·5	0·86	0·56	20	35	40
4	Pummelo	(*a*) 7 25	73·1	60·5	2·11	0·75	28	40	20
		(*b*) 7 25	34·0	37·5	1·39	1·21	15	38	15
		(*c*) 7 25	32·5	55·2	0·90	1·40	20	35	15
5	Acid lime	(*a*) 9 2	108·0	68·2	1·25	0·64	14	26	12
		(*b*) 9 2	94·3	28·1	1·61	0·65	19	17	16
		(*c*) 9 2	78·1	48·5	1·07	0·74	26	36	13
6	*Gabbu-chinee*	(*a*) 10 2	189·8	12·0	0·68	0·25	11	17	15
		(*b*) 10 2	124·0	12·1	0·75	0·35	14	19	17
		(*c*) 10 2	72·2	42·7	0·76	0·53	23	19	25
7	Sweet orange (*chinee*)	(*a*) 7 28	120·0	44·0	1·37	0·40	26	14	24
		(*b*) 7 28	91·0	48·5	1·31	0·58	20	22	18
		(*c*) 7 28	87·5	46·2	1·08	0·43	16	16	17
8	*Billi-kichili*	(*a*) 10 4	94·8	24·2	1·32	0·48	6	23	21
		(*b*) 10 4	89·0	17·3	1·36	0·43	16	17	16
		(*c*) 10 4	75·7	44·0	1·17	0·46	12	20	24

Gabbu-chinee :—The largest tap-root extending up to 189·8 cm. from soil surface was found in this variety. Roots appear bare in comparison with other varieties. The tap-root fairly thin. Sparse and poor spreading laterals with little fibre.

Sweet orange (*chinee*) :—Well balanced root system between medium coarse laterals and moderately abundant fibre. Stout tap-root. A large proportion of spreading laterals and fibre in upper layers of soil.

Billi-kichili :—Resembles *gabbu-chinee*, except that in this variety the roots are less penetrating and have slightly better spreading laterals. Fair amount of fibre towards the lower soil layers.

A point of interest revealed from this study is the enormous depth to which the roots of some of the citrus varieties find their way at a very early stage of their life in the seed beds. The close planting in seed beds is undoubtedly the primary cause for this root habit. Since the roots are usually pruned to a depth of 15 to 30 cm. at the time of transplantation, the study indicates the enormous extent of pruning (in one instance as much as about 160 cm.) given to the roots.

In addition to the above-mentioned studies, 45 more root systems of seedlings of different varieties of citrus were also examined at different periods. The observations made on these plants appeared to confirm, in general, the descriptions summarised above.

In Table XXII are given the percentage of success obtained by transplanting the seedlings of these eight different varieties during the same year.

TABLE XXII

Percentage of living plants in different varieties of citrus after transplantation

Serial No.	Variety	Date of sowing	Date of transplanting	No. of seedlings transplanted	Percentage of success
1	*Kichili*	17-11-35	27-6-36	788	89·88
2	*Gajanimma*	17-11-35	30-6-36	612	87·75
3	*Gajanimma*	18-11-35	1-7-36	414	86·71
4	*Jamberi*	12-11-35	25-6-36	738	97·15
5	*Jamberi*	19-12-35	3-7-36	84	95·23
6	Pummelo	17-12-35	9-7-36	42	100·00
7	Acid lime	23-11-35	7-7-36	436	73·39
8	*Gabbu-chinee*	24-10-35	3-7-36	807	67·41
9	*Gabbu-chinee*	24-10-35	5-7-36	833	56·42
10	Sweet orange (*chinee*)	23-11-35	9-7-36	36	100·00
11	*Billi-kichili*	19-11-35	8-7-36	109	64·22

From a reference to Tables XXI and XXII and descriptions of root systems, it appears possible that the success in transplanting is dependent upon the character of the root system. An abundance of fibre in the upper soil layer or shallow scaffolding of laterals appear to be favourable for ensuring a good stand.

FIG. 1

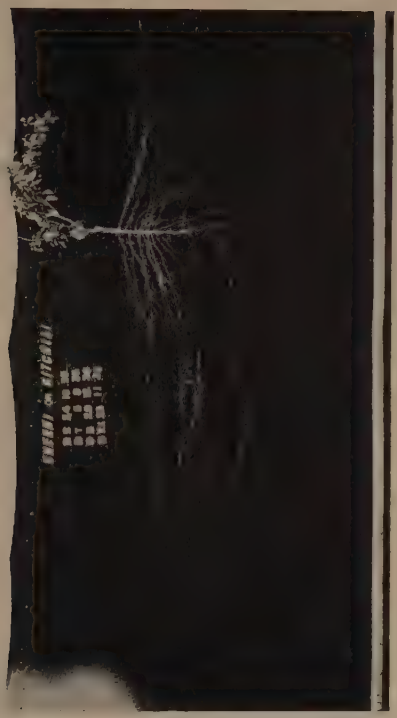

FIG. 2

FIG. 3

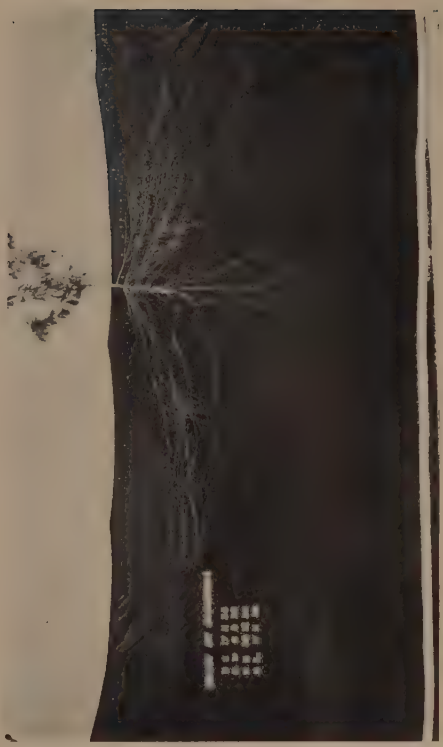

FIG. 4

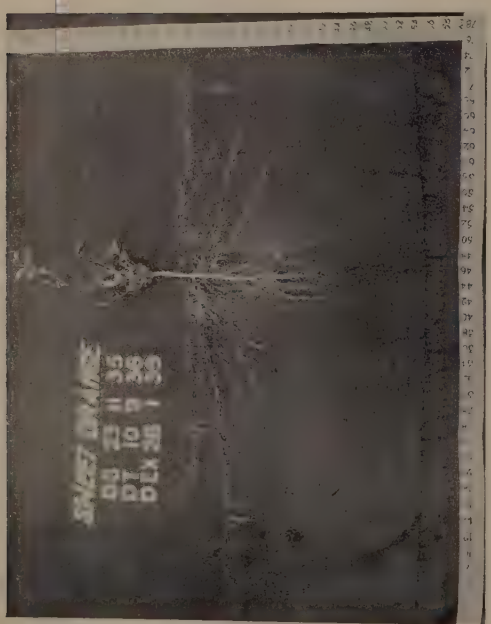

FIG. 1

FIG. 2

FIG. 3

FIG. 4

During the period, October 1937 to March 1938 and again during 1938-39, one budded *chinee* orange plant on each of the eight rootstocks and an unworked seedling of the same rootstock variety, out of the batches of plants specially raised for this purpose were excavated for a study of root systems (Plates XVIII—XXI). The data collected in the course of former root excavations are summarised in Tables XXIII and XXIV.

It is realised that the data furnished in Tables XXIII and XXIV are not sufficient to gather an accurate idea about the varietal characteristics or of the peculiar habits of the unworked or budded plants on any given variety. Notwithstanding these limitations, the outstanding differences observed in these root excavations are considered to be of sufficient interest to be summarised in the present paper as will also be evident from the perusal of the following inferences.

(*a*) In the case of *gabbu-chinee* and country sour orange rootstocks, the height of the bud-sprouts has shown to be even more than the height of the unworked seedlings. Whether this surprising fact is due to the variation in the individuals or due to invigorating effect of these particular stock-scion combinations, it will be impossible to clearly state on the basis of the variable data.

(*b*) Of all the varieties, sweet orange has shown the least growth in terms of height both as an unworked seedling and as a rootstock.

(*c*) In regard to stem diameter measurements, *kichili* has shown relatively poor growth both in worked and unworked seedlings.

(*d*) The total weight of the plants above ground is found to be more in budded plants on country sour orange and *jamberi* than in the unworked seedlings of these varieties. This, again, is at present an inexplicable point. Sweet orange, country sour orange and *kichili* have registered relatively low weight of top growth, both in the case of unworked seedlings and when used as rootstocks for orange.

(*e*) Except on *gajanimma*, pummelo and sweet orange, the budded plants have penetrated into greater depths of soil than the unworked seedlings. *Kichili*, however, has proved to be relatively shallow rooted both as an unworked seedling and as a rootstock for sweet orange, while country sour orange and *khatta* are on the other extreme.

(*f*) The budded plants on *gajanimma* and *gabbu-chinee* have foraged on a large area than the seedlings of these two varieties. Both the worked and unworked seedlings of *gajanimma* and *khatta* have recorded relatively large spread of roots, while *kichili* and orange have recorded the least in both cases.

(*g*) *Kichili*, *gabbu-chinee* and sweet orange have shown a larger number of laterals when employed as rootstocks than as seedlings. The number of lateral roots is relatively large on both worked and unworked seedlings of *jamberi* and *khatta*, and relatively small in *kichili*.

TABLE XXIII

Records on root systems of unworked seedlings of different varieties of citrus

Variety	Date of excavation	Age at the time of excavation		Height of plants	Girth at 3 in. height from the ground	Weight of shoots	Depth of roots	Spread of roots	Maximum length of lateral roots	No. of laterals	Total weight of roots	Weight of coarse roots	Weight of fibrous roots	Weight of fibre as percentage of total weight of roots	Shoot weight / Root weight Ratio
		Month	Days	cm.	cm.	gm.	cm.	cm.	cm.		gm.	gm.	gm.		
Kichili	21-11-37	24	27	87·00	3·77	59·6	87·0	150·0	82·0	61	37·9	25·6	12·3	32·47	1·57
Gajanimma	14-12-37	24	27	100·00	6·29	278·0	151·0	410·0	262·0	173	249·0	151·0	98·0	39·36	1·12
Gabbu-chinee	29-11-37	25	9	75·00	5·72	92·0	125·5	264·0	145·0	115	148·0	95·0	53·0	35·81	0·62
Khatta	31-1-38	25	13	120·00	6·60	271·0	142·0	500·0	270·0	195	373·0	233·0	140·0	37·50	0·73
Pummelo*	10-2-38	25	23	115·00	5·88	165·0	176·0	260·0	130·0	150	232·0	112·0	120·0	51·72	0·71
Sweet orange	13-2-38	26	20	56·50	3·61	40·0	143·0	140·0	80·0	110	60·0	24·0	36·0	60·00	0·67
Sour country orange	19-2-38	26	0	46·00	3·42	48·0	150·0	251·0	130·0	148	65·9	29·6	36·3	55·08	0·73
Jamberi	4-3-38	25	17	110·00	5·37	119·0	126·0	400·0	235·0	178	295·0	180·0	115·0	38·98	0·40

* The root system of this plant is not normal for the reason given elsewhere.

TABLE XXIV

Records on root systems of chinee *orange plants on different rootstocks*

Rootstock variety	Date of excavation	Age of scion at the time of excavation in months and days	Age of stock at the time of excavation in months and days	Height of bud-sprouts in cm.	Girth of scion at 1 in. above the point of insertion, in cm.	Girth of stock at 3 in. above the ground level in cm.	Weight of scion in gm.	Weight of stock in gm.	Total weight of plant above the ground level in gm.	Depth of roots in cm.	Spread of roots in cm.	Maximum length of laterals in cm.	Number of laterals	Total weight of roots in gm.	Weight of coarse roots in gm.	Weight of fibre roots in gm.	Weight of fibre as percentage of total weight of roots	Ratio:— Shoot weight / Root weight
Kichili	8-11-37	10 9	24 10	46·8	1·87	2·73	28·00	16·95	44·95	120·0	102·5	60·5	66	34·4	23·8	10·6	30·52	1·31
Gajanimma	24-11-37	10 25	24 7	58·6	2·64	5·09	46·80	16·50	63·30	117·0	425·0	225·0	63	93·0	66·0	27·0	29·03	0·68
Gabbu-chinee	21-1-38	12 22	26 23	93·0	3·08	6·66	59·00	25·60	84·60	139·0	285·0	185·0	173	137·2	78·1	59·1	43·08	0·63
Khatta	4-12-37	10 22	23 16	60·5	3·52	5·91	83·00	47·00	130·00	145·3	415·0	230·0	150	169·0	114·0	55·0	32·54	0·73
Pummelo	4-2-38	12 22	25 17	63·5	2·51	4·53	32·00	27·00	59·00	115·5	210·0	150·0	120	108·0	43·0	65·0	60·19	0·55
Sweet orange	27-2-38	12 28	27 4	34·5	2·36	3·56	10·00	9·50	19·50	99·0	125·0	69·5	124	42·5	23·0	19·5	45·88	0·46
Sour country orange*	8-3-38	14 9	26 20	63·0	2·98	3·82	34·00	19·00	53·00	160·0	235·0	201·0	130	62·0	43·0	19·0	30·65	0·85
Jamberi	23-2-38	13 29	25 6	56·0	3·90	4·93	80·00	50·00	130·00	150·0	290·0	165·0	153	145·0	100·0	45·0	31·03	

* The root system of this plant is not normal for the reason given elsewhere.

(*h*) The total weight of the roots has apparently been considerably reduced in worked seedlings of *gajanimma*, *khatta*, pummelo and *jamberi*. Both the worked and unworked seedlings of *khatta* and *jamberi* have produced relatively heavier root systems, while *kichili*, sweet orange and country sour orange have produced relatively lighter roots.

(*i*) The weight of fibrous roots is observed to be more on worked seedling of *gabbu-chinee* than in the case of unworked. Marked reduction in the weight of fibre is noticed in the worked seedlings of *gajanimma*, pummelo and *jamberi*.

(*j*) In proportion to the entire root system, the fibre is more on worked seedlings of *gabbu-chinee* and pummelo than on unworked. The proportion of fibrous roots is found to be relatively large on both the worked and unworked seedlings of pummelo and sweet orange, and low in *kichili*, *jamberi* and *khatta*.

(*k*) In relation to root, the top-growth has registered larger increase on worked seedlings of *gabbu-chinee*, country sour orange and *jamberi* than on unworked, while it remains the same in the case of *khatta*. *Kichili* has shown a larger top-growth in proportion to root, both as a rootstock as well as an unworked seedling, while sweet orange has shown proportionately the least top-growth in both the classes.

In the case of *kichili* seedling (Plate XX, fig. 1) and the budded orange on *jamberi* (Plate XXI, fig. 4), they were planted close to pits which had been dug about six months before their planting. The pits had been refilled a short while before the planting of the trees. The loose media inside these pits has obviously brought about a marked influence on the root growth. The large increase in the size and number of lateral and fibrous roots inside the dug-out area on one side of the figure as contrasted with the normal development in the rest of the soil serves to emphasize the considerable influence that soil conditions exert on the root system of plants.

The excavation and study of root system was repeated during 1938-39 and the observations collected during that year are set forth in Tables XXV and XXVI.

The following inferences seem to be warranted from the data :—

(1) Sweet orange has produced the smallest top growth in terms of height and stem thickness both as an unworked seedling and as a rootstock during the two years under study. This observation is further confirmed by the data relating to the weight of plants above ground level. In this respect, *gajanimma*, *jamberi* and *khatta* would seem to mark the other extreme in producing the largest weight of top growth.

(2) Almost the same position as that mentioned above has been maintained by sweet orange both as an unworked seedling and as a rootstock in regard to the depth and spread of roots, total weight of roots, weight of coarse roots and weight of fibrous roots, whereas *jambari*, *khatta* and *gajanimma* maintain the premier position in regard to these characters.

TABLE XXV

Records on root systems of unworked seedlings of different rootstock varieties

(*Citrus root studies*)

Variety	Date of excavation	Age at the time of the excavation		Height of the plant	Stem thickness at 3″ from ground level	Weight of the shoot	Depth of the roots	Spread of the roots	Maximum length of the laterals	Total weight of roots	Weight of coarse roots	Weight of fibrous roots	Weight of fibre as per cent of the total weight of roots	Shoot weight / Root weight Ratio
		M.	Days	cm.	cm.	gm.	cm.	cm.	cm.	gm.	gm.	gm.	gm.	
Gabbu-chinee	10-12-38	37	12	102·50	1·47	204·50	146·50	411·30	245·00	171·17	136·70	34·47	20·10	1·19
Khatta	18-12-38	36	0	154·30	3·21	1,192·00	147·25	617·00	400·00	500·50	430·00	70·50	14·10	2·36
Jamberi	22-12-38	35	5	168·00	3·20	1,283·70	190·40	441·80	405·00	680·50	595·00	85·50	12·56	1·88
Gajanimma	17-1-39	38	0	131·00	3·60	1,383·50	160·00	639·80	350·40	509·50	475·00	34·50	6·70	2·71
Sweet orange	25-1-39	38	3	50·70	1·13	49·00	91·40	177·70	101·50	49·00	31·00	18·00	36·70	1·00
Country orange	31-1-39	37	23	134·60	2·70	616·50	320·00	512·80	256·40	240·00	190·00	50·00	20·80	2·56
Pummelo	2-2-39	37	16	127·00	2·23	430·00	142·20	304·70	067·60	200·00	140·00	60·00	30·00	2·15
Kichili	7-2-39	39	13	104·00	1·70	366·00	134·60	563·60	446·70	198·00	169·00	29·00	14·60	1·85

TABLE XXVI

Records on root systems of chinee *orange plants on different rootstocks*
(Citrus root studies)

Variety.	Date of excavation	Age of scion at the time of excavation, in months and days	Age of rootstock at the time of excavation in months and days	Height of bud-sprout	Stem thickness of the scion at 1 in. above bud-joint	Stem thickness of the rootstock at 3 in. above ground level	Weight of scion	Weight of rootstock	Total weight of plant	Depth of roots	Spread of roots	Maximum length of laterals	Total weight of roots	Weight of coarse roots	Weight of fibrous roots	Weight of fibre as percentage of total weight of roots	Ratio :— Shoot weight / Root weight
				cm.	cm.	cm.	gm.	gm.	gm.	cm.	cm.	cm.	gm.	gm.	gm.		
Gabbu-chinee	12-10-38 to 16-10-38	21 14	35 17	73·66	1·62	1·62	85·71	35·71	121·42	127·00	386·00	218·44	85·00	64·28	21·42	25·00	1·42
Khatta	20-10-38 to 25-10-38	23 5	33 28	76·50	2·50	1·90	321·00	57·00	378·00	120·00	441·40	329·00	155·00	127·00	27·50	17·70	2·44
Jamberi	26-10-38 to 6-11-38	21 7	34 9	97·80	2·79	3·10	565·80	95·00	660·80	147·50	378·30	418·00	356·26	294·50	61·76	17·30	1·85
Gajanimma	10-11-38	21 11	36 5	97·50	1·98	2·72	415·00	74·00	489·00	256·40	543·30	398·60	276·00	238·50	37·50	13·58	1·77
Sweet orange	2-12-38	22 20	36 9	56·70	1·42	1·78	89·00	16·00	105·00	117·00	246·20	167·60	72·00	47·00	25·00	34·72	1·46
Country orange	29-11-38	23 0	35 2	80·00	1·42	1·86	186·00	42·00	228·00	132·00	414·00	304·80	175·00	140·00	35·00	20·00	1·13
Pummelo	5-12-38	22 6	35 18	53·30	0·84	1·64	73·00	29·00	102·00	132·10	256·40	134·60	78·00	53·00	25·00	32·05	1·31
Kichili	23-11-38	21 24	37 3	91·50	1·89	2·50	401·00	62·00	463·00	147·20	472·20	391·00	244·82	216·00	28·82	11·77	1·89

(3) As against all other rootstocks and unworked seedlings, sweet orange seedling and rootstock have produced the maximum percentage of fibre in the root system in both the years under study as well as possessed a greater root weight in proportion to the top weight. *Kichili* and *gajanimma*, when employed as rootstocks, on the other hand, have produced the least proportion of fibre in both the years. Pummelo perhaps comes close to sweet orange in regard to this character.

(4) *Jamberi*, *gajanimma*, sweet orange and country orange have registered a greater length of lateral roots when employed as rootstocks than as unworked seedlings. In a similar manner, *gajanimma*, sweet orange and *kichili* have penetrated to a greater depth when used as rootstocks. The percentage of fibre in budded plants has also been greater on *gabbu-chinee*, *khatta*, *jamberi*, *gajanimma* and pummelo than on unworked seedlings, while a relatively greater weight of roots is observed on *gabbu-chinee*, *khatta*, sweet orange and *kichili* rootstocks than on the unworked seedlings of the respective varieties. These various instances would seem to show the various directions in which the scion probably operates in modifying the inherent rooting habit of the seedling rootstocks.

(5) A maximum depth of 320·00 cm. has been registered by a country orange seedling of about 38 months old, while in budded plants *gajanimma* rootstock has shown a maximum depth of 256·40 cm. with the scion of only about 21½ months of age. *Gajanimma* has also contributed the largest spread of roots both in unworked and budded plants with a maximum of 639·80 cm. and 543.30 cm. respectively.

(6) Sweet orange is marked out as the poorest both as a seedling and as a rootstock in regard to the depth and foraging power of the root system, although as a rootstock it appears to have definitely improved its rooting power. Since this variety has consistently produced the maximum percentage of fibre and proportionately greater root weight, it would seem that its apparently poor rooting habit cannot be considered as a disadvantage by itself, and that its inferiority seems to be mainly due to the relatively poor top growth during its initial period of life.

The above observations are of special interest in affording some surprising indications of the enormous foraging power of roots of certain citrus varieties. The vast difference in the root spread between the plants on various rootstocks as evidenced by the maximum spread of 543·30 cm. on *gajanimma* of about 21½ months of age after budding and the minimum of 246·20 cm. on sweet orange of about 23 months of age after budding serve to emphasize the value of determining the optimum orchard spacing for oranges of about the same age on different rootstocks. That the criterion for judging the suitability of a rootstock does not appear to lie solely on the depth or spread of its root system but also on the proportion of fibre and root weight relative to shoot weight is yet another fact of possible importance indicated from these various studies.

It would also appear from a perusal of the foregoing data that there is a wide difference in the root systems of *kichili* and country orange. This fact strengthens the popular belief that these two are distinct varieties.

Discussion

Of the various rootstocks used in the investigations reported herein, useful information on the relative performance of such rootstocks as sour orange, sweet orange and rough lemon under diverse conditions of growth and culture are already available in citrus literature. To a lesser extent, the adaptability rootstock effect and incompatibility of pummelo, acid lime and *C. tangerina* Hort. Tanaka as observed in certain countries have also been made available by the respective workers. A valuable summary of the salient points in these various rootstock trials has been prepared by Hatton [1932]. The rootstock trial with *chinee* orange scion discussed in this paper includes two other citrus rootstock species and one new strain of sweet orange. In neither of these cases, any work has been done so far in any part of the world. Since these have presumably originated as chance seedlings in this part of India and have been observed to withstand neglect and drought conditions to a remarkable degree in certain parts of the Ceded districts of Madras Province, it is considered useful to test their rootstock potentialities along with those of the well-known rootstocks in use elsewhere.

The soil of the plots in which the present investigations have been conducted being red loam of great depth, the inferences deduced and presented in this paper can but be of application only to similar conditions. It is necessary to bear this in view, especially while discussing the various facts that have emerged from the root studies and growth increment data.

The data collected on the percentage of apogamic seedlings produced by different varieties indicate that the strains of *jamberi*, *gajanimma*, *kichili* and acid lime used in these studies are highly polyembryonic, those of pummelo, *chinee* orange, and *mokri* are monoembryonic and those of *herale* and *gabbu-chinee* are slightly polyembryonic.

Since the present data are based on seedling counts and not on embryo counts, the above inferences can be only suggestive and not conclusive. As a matter of fact these inferences in respect of *chinee* and *mokri* are contrary to the findings of Webber [1931], who has determined the range in percentage of apogamic embryos in sweet oranges to be 40 to 95, and in citron 40 to 50. Webber has also found that sour orange is highly polyembryonic, accounting for 75 to 85 per cent of apogamic embryos. Quoting the findings of Torres who had worked with 50 seed samples in Philippines, Traub and Robinson [1937] have shown that the range of embryos per seed varies from 1 to 12 in sweet oranges, 1 to 6 in rough lemon, 1 to 3 in sour oranges and 1 to 2 in limes. Pummelo was the only variety that did not exhibit polyembryony. According to Torres, the average number of embryos per seed was the highest in sweet orange (4·88) and least in sour orange among the nine polyembryonic varieties tested. The data adduced by Webber and Torres, therefore, differ materially from each other in regard to the extent of polyembryony in sour oranges, while in respect of sweet orange the data presented in this paper on

the basis of a study with 100 seed samples vary from those of either of these workers. In a separate trial with about eighty seeds of *chinee* orange, it was also found that not a single seed produced more than one seedling. Torres [1936] has also shown that the correlation between embryo counts is statistically insignificant, although he argues that the more embroys the seed contains the weaker they will be and the less their chance of successful germination. In the face of all these various findings, the only valid inference that is warranted is that the pummelo is definitely monoembroynic, and the apparently monoembryonic nature of *chinee* orange and *mokri* may perhaps be due either to the variation between the horticultural varieties of sweet orange and citron or to the effects wrought by environment in the tree or in seed beds.

With a variable material as that obtained from seedling rootstock, the first problem that confronts the worker initiating the field experiments with citrus is that of increasing the uniformity to the maximum extent possible. The system of roguing out of the variants and under-sized seedlings and selection of seedlings from the modal class as practised in these investigations has clearly narrowed down or restricted the variability in so far as the quantitative measurements of growth are concerned. It is to be seen if these measures will reduce the variability in respect of tree performance also in later years.

The proportion of seedlings in the modal class are found to be the largest in acid lime, *jamberi* and *kichili* and least in *gajanimma*. The under-sized and weak seedlings have formed the largest proportion in *gajanimma* and least in acid lime. On an analysis of the graded seedlings after transplantation from seed to nursery beds, it is however, found that *kichili* is the most variable. Since a large percentage of seedling variants had been separated out in the case of *gajanimma* and a very large percentage amounting to 43·34 of under-sized and weak seedlings had also been rouged out, it is obvious that high uniformity observed in the graded seedlings of this rootstock cannot be considered to afford a true index of its inherent variability. Similarly, the uniformity of *gabbu-chinee* as observed in the final batch of seedlings is due to the larger number of variants budded previously and also the high proportion (35·42 per cent) of under-sized and weak seedlings rogued out. On the other hand, in spite of the separation of a large number of vigorous variants and of 36·60 per cent of under-sized and weak seedlings in *kichili*, this variety has contributed to exhibit a very high variability in the finally graded batch of seedlings. In the case of acid limes, however, the proportion of vigorous variants and of weak and under-sized seedlings was relatively small, notwithtanding which fact it has exhibited very high uniformity in the finally graded batch of seedlings. These various facts would show that, of the seedling progenies under study, acid lime is the least variable and *kichili* the most variable of all.

Webber [1932] has recommended that the selection of seedlings in citrus nursery should include the discarding of smallest seedlings to the extent of about 25 per cent in the seed bed and roguing out of all variant seedlings irrespective of size just prior to the plantings up to an extent of about 5 per cent. In general, the process of roguing out of small and under-sized seedlings and of variants and a further selection of uniform budlings as adopted in these trials are in conformity with the recommendations of Webber and tend to impart the maximum uniformity in the budlings.

Both prior to the budding stage as well as till the time of planting, the *jamberi* rootstock has occupied the front rank in the matter of producing plant vigour. *Gajanimma* is on a par with *jamberi* in both the above-mentioned respects, which fact is also in consonance with the popular experience of the growers of this variety. Working with apple trees, Sax and Gowen [1923] have shown that under similar conditions, the trees show early and permanent differences in size, and these differences apparently depend upon variability of the seedling rootstocks. As to whether this early revelation of clear differences in growth and vigour of seedlings will furnish a clue to its later behaviour or performance in the orchard is a point of undoubted interest, which cannot be elucidated at the present stage of these trials.

It must, however, be mentioned that the rate of growth as well as the vigour is a factor likely to be influenced to a considerable extent by the individual parents within a variety. This is borne out from the differential pre-orchard performances of the sweet orange seedlings of two different parents.

From the point of the nurseryman and citrus grower who would naturally welcome a knowledge of certain easily discernible plant characters associated with several aspects of the nursery and orchard operation and performance, the data presented in the paper are likely to prove interesting. For instance, it has been brought out that height measurements of seedlings do not afford any reliable indication of the suitability of the seedlings to receive buds, as the latter feature is mainly governed by the stem-thickness of rootstocks. Similarly, the rate of growth as observed in any particular period does not furnish a reliable clue to the ultimate vigour or size of the plant, as the rate of growth has been found in the case of *chinee* seedling during the pre-orchard life to be even more than the more vigorous *jamberi*. With regard to the 'take' of buds also, no reliable method is furnished from the data presented herein of determining the suitability of the varieties on the basis of their growth or vigour, as the varieties that have produced the maximum 'take' neither belong to the most vigorous nor to the least vigorous class.

It is observed that *billi-kichili* and pummelo have produced very high 'take' of sweet orange buds at one time and a relatively small 'take' at a later stage, while *gabbu-chinee* has produced the least at both times. Since these results have been obtained only during certain seasons, and since there is likely to be some variation in the optimum period for bud-insertion between varieties, these results of bud 'take' are not intended to furnish a correct index. It is also possible that the period taken to reach the optimum stage for bud 'take' may differ to a certain extent between varieties. Evidence in support of this assumption is afforded from the fact that *mokri* which is usually considered to produce a very high 'take' in North India has not produced similar result in the present trials. These various points seem to indicate the fact that the optimum season for budding is not the same for all varieties in all tracts and in all seasons.

The differential 'take' of buds with acid lime and sweet orange scion varieties particularly on *kichili* rootstock has been clearly brought out from these investigations. This has already been shown to establish the fairly well-understood phenomenon that different scion varieties respond differently to a given rootstock.

The merits of a given rootstock has to be judged not only on the basis of vigour and yield but also on its susceptibility to diseases and pests and on the extent of its compatibility with the scion variety. Although evidence has not been presented in the foregoing pages on the former factor, field observations have, however, revealed that *gajanimma* is the most susceptible of all the rootstocks to gummosis and pummelo and acid limes probably to withertip and canker respectively. Regarding the compatibility it is too premature to deduce any inferences, although the slight differences between the rootstock and scion-stem girth measurements seem to afford some preliminary indications of partial incompatibility. With the collection of such measurements in future years it is expected that a more definite idea would become available.

It is recognised that the number of individuals excavated in each variety for the purpose of root studies are limited and, therefore, definite inferences are not warranted on the basis of the data gathered from these investigations. It has to be remembered, however, that in an investigation of this type, practical difficulties in the way of handling large populations within a reasonably short period are enormous, which fact also rules out the observance of identical conditions for the conduct of these studies. It is on these grounds that the extensive literature comprising results often based on the studies of root systems of a single individual can be justified. A further evidence in support of the justification of these studies of root systems and of the inferences drawn therefrom are afforded by the findings of Swarbrick and Roberts [1928] that trees budded on the stems of seedlings have roots which are typical of the different seedlings.

Apart from the several interesting peculiarities of the varieties in regard to their root habits, certain valuable observations and inferences of practical value have emerged from these studies. The correlation between the success in transplantation of seedlings and the abundance of fibre in the upper soil layer or the existence of shallow scaffolding laterals is one such information to guide the growers in determining the optimum period of transplantation. If the varieties with low proportion of fibre in upper soil layers are transplanted in early stages, the chances of higher mortality of seedlings are necessarily great. On the other hand, the same seedlings if allowed to remain in seed beds for a longer period to produce more fibre or shallow laterals the success in transplantation becomes greater.

The enormous foraging power of roots of certain varieties as evidenced by the maximum depth of 189 8 cm. of about a ten-months-old *gabbu-chinee* seedling and of 320·00 cm. of a 38-months-old seedling of country orange and of 256·40 cm. of a budded orange plant on *gajanimma* after about 21½ months of bud-insertion are sufficient to show the enormous area covered by the citrus roots in soils of fairly open texture. This fact is further brought out from the data relating to the spread of roots, which in the *gajanimma* seedling referred to above had reached the maximum of 639·80 cm. and in the budded plant on the same rootstock to 543·30 cm.

The above observations are not exactly in accord in some important respects with those made by other workers elsewhere. Waynick and Webber [1930] have stated that in North America about 90 per cent of the active rooting area of citrus is in the upper 48 in. of the soil. West [1934] in Australia

has, on the other hand, found that the greatest concentration of roots of citrus on rough lemon rootstock was at 30 to 50 cm. from the soil surface. Allwright [1935] has judged that in a 14 year old Washington Naval orange plantation, three-quarters of the roots of the trees were in the top two feet and very few deeper than three feet. Gregory [1935] in Trinidad has found that the majority of the feeding roots in three year old Marsh grapefruit trees were at a distance of 3-18 in. from the trunk. In the same study, Gregory has shown that the lateral spread of manured trees exceeds the average spread of the branches, which was 42 in. He therefore proceeds to suggest that the fertilizers should be spread evenly over a wide circle starting 3 in. from the trunk. On the basis of other published works, Gandhi [1939] has also pointed out that the roots of citrus are capable of extending to a distance of two to three times the spread of branches. The data presented in this paper clearly suggest that tree spread is not a reliable index of the feeding area of the roots, which, though depending on the variety of rootstock, nevertheless covers a very much larger orchard space than that actually encompassed by the top-growth. That the spread of apple roots in sandy soils is twice to three times as far as the branches has also been pointed out by Rogers [1934], and Rogers and Vyvyan [1934], who have consequently emphasized the necessity for manuring well beyond the spread of the branches. Cultivating only in a small circle round the tree and application of manures in a limited space have also been pointed by Susa [1934] to be responsible for restricting the absorbing root area. Provision of small basins of two to three feet wide around the tree trunk for application of water and fertilizers, as is usually done in the young citrus plantations in this tract is, therefore, hardly sufficient to give the full benefit of these treatments to the growing tree. Nor will the determination of proper spacing merely on the basis of spread of branches will prevent root interlacing and the consequent competition between adjoining trees for soil moisture and nutrients. A definite alteration in citrus cultural practices, especially in the matter of spacing of trees, application of water and fertilizers, are therefore indicated under similar soil conditions as those employed in the present investigations.

On a consideration of all the relevant characters as brought out from the present studies of the pre-orchard life of the various rootstocks, it would seem that *jamberi* is the most suitable rootstock for *chinee* orange and acid lime. This variety has produced the highest germination, largest number of apogamic seedlings, a very high proportion of vigorous variants ready for budding within a year from sowing, a very large proportion of seedlings in the modal class and a very high ' take ' of orange and acid lime buds in different seasons. The seedlings also transplant well and make a good stand in nursery beds. The root system is well distributed, possessing an abundant fibre and good depth. The scions also grow very vigorously during the pre-orchard life. Furthermore, the variety has not shown signs of susceptibility to any of the more important citrus diseases. *Gajanimma* though has shown to be a virgorous rootstock suffers from such serious defects as poor germination, relatively low proportion of seedlings in the modal class indicating high variability and a high susceptibility to gummosis. Pummelo, being monoembryonic, cannot possibly find favour as a rootstock. It has further produced varying percentages of ' take ' with scion buds and is possibly susceptible to withertip disease. The varying ' take ' of buds on *billi-kichili*, poor

transplanting and the low proportion of vigorous seedlings variants are the defects which rule out this variety from the class of suitable rootstocks. Low percentage of apogamic seedlings and varying 'take' of scion buds are defects in *mokri*, while *gabbu-chinee* merits no consideration, because of its poor 'take' of both orange and acid lime buds, relatively low production of apogamic seedlings and poor transplanting habit possibly due to its bare root system in early stages. The production of abnormally deep root system in seedlings of this variety is, however, a character of some value, which deserves to be exploited. *Chinee* orange is very slow in growth both before and after working, besides producing a poor germination and its non or low production of apogamic seedlings. Its relatively higher weight of root relative to top growth, easy transplantation and well-balanced root system are, however, points that require to be considered in its favour. *Kichili* has shown a poor 'take' with acid lime scion and has also not produced a very high germination of seeds or a high uniformity in seedlings. It has also sparse fibre in the root system in early stages. But for these few defects and possibly its relatively slow growth in the beginning, this rootstock can well be classed as one among the desirable. The data relating to *herale* is not comprehensive enough, even though its defects in the matter of poor germination and low percentage of apogamic seedlings have been brought out. Acid lime has been found to be susceptible to canker and to be not so easy for transplantation as the *jamberi* nor as efficient in producing vigour in the budlings. In other respects, it obviously possesses most of the favourable characters of a good rootstock.

The foregoing evaluation of the rootstocks cannot possibly furnish any clue to their future orchard performance. Nevertheless, the information presented in this paper is essential for a complete understanding of the problem of rootstock-scion relationship in cultivated citrus. It is on these grounds that the author ventures to present these results to the citrus-growing public and the research workers in this field.

Summary

(1) *Jamberi* has uniformly produced the highest germination in seed bed and is closely followed by pummelo, while *chinee* orange, *herale* and *gajanimma* have been found to produce relatively poor germination.

(2) The percentage of apogamic seedlings actually obtained in seed beds has been found to be the largest in *jamberi*, *gajanimma*, *kichili* and acid lime, while it was relatively low in *herale* and *gabbu-chinee*. Pummelo has proved to be distinctly monoembryonic.

(3) The proportion of vigorous growing variants that becomes available for budding within a year after sowing is found to be the largest in *jamberi*, *gajanimma*, *mokri* and *kichili* and relatively small in *chinee* orange, *billi-kichili*, *gabbu-chinee* and acid lime. For expediting the production of budded citrus plants, *jamberi* and *gajanimma* appear to furnish the most suitable material.

(4) Within a year after sowing, the size of seedling rootstocks as judged by their height and stem diameter measurements has been found to be the largest in *jamberi* and *gajanimma* and least in *chinee* orange and *billi-kichili*.

(5) The height measurements of the plants, do not seem to afford a reliable index of the suitability of the seedling rootstocks to receive buds.

(6) The rate of growth in seed beds appears to be influenced to a considerable extent by the individual parent and not the variety or the species.

(7) The differential ' take ' of buds on *billi-kichili* when worked at two different periods of growth establishes the fact that the optimum period for bud-insertion varies with the different rootstocks, and may also vary in different tracts and seasons.

(8) *Jamberi* and *gajanimma*, have produced invariably very high ' take ' of buds while *gabbu-chinee* has shown relatively low bud ' take '.

(9) Different scion varieties are found to respond differently on a given rootstock variety in regard to bud ' take ' ; and acid limes in general have contributed to a lower ' take ' of buds than the *chinee* orange scion.

(10) Acid lime has proved to be the least variable and *kichili* the most variable of the rootstocks under study.

(11) The repeated selection of plants has been found to be efficacious in restricting the variability of citrus seedling rootstocks.

(12) Although no definite idea about the rootstock-scion compatibility has been revealed from the data, it is however indicated that, pummelo and *gajanimma* have produced relatively larger rootstock stem thickness than those of scion stems, while *chinee* has produced the narrowest margin between these two measurements.

(13) With *chinee* scion, *jamberi* has registered the highest growth increments from seedling to planting stage and has also produced the largest sized plants at the commencement of orchard life.

(14) Although *chinee* seedlings were the lowest sized at the time of planting, they have recorded larger girth increment during pre-orchard life, possibly because of the fact that the inhibitive effect of bud-insertion has been non-operating in its case.

(15) During pre-orchard life, pummelo *billi-kichili* and acid lime have produced least growth increments.

(16) *Gajanimma* as a rootstock is on a par with *jamberi* in respect of contribution to scion vigour at the commencement of orchard life.

(17) With acid lime scion also, *jamberi* has produced the largest stem thickness, while acid lime the least at the time of planting.

(18) Notwithstanding the fact that individuals within a variety possess root systems of widely differing characteristics, certain specific or varietal characters have been brought out from the root studies and presented in the foregoing pages.

(19) The enormous depth to which the seedling root penetrates at a very early stage of its life has been emphasized and the enormous extent of root-pruning done at the time of transplantation indicated.

(20) Success in transplanting of seedlings has been shown to be dependent on the character of the root system. An abundance of fibre in upper soil layers or of shallow scaffolding laterals have been pointed out to be favourable for ensuring a good stand.

(21) From a consideration of the root systems of worked and unworked seedlings, the possible directions in which the scion modifies be rooting habits of the seedling rootstock has been indicated.

(22) That the merits of a seedling rootstock cannot be judged solely on the depth and foraging power of root system but should also be based on the proportion of fibre and of root-weight are points that have been made clear from the present studies.

(23) The enormous variation in the area combed by the root systems of different varieties when grown as seedlings or as rootstocks even at a very early stage of the plant life, as well as the vast extent covered by the roots at such an early stage, serve to emphasize the necessity of determining separately the optimum orchard spacing for *chinee* orange worked on different rootstocks on the basis of root studies. These also indicate that the popular practice of applying irrigation water and fertilizers in a small area around the plant is not adequate to meet the entire needs of the plant concerned.

Acknowledgement

The present investigations form a part of the programme of work of the fruit research scheme financed by the Imperial Council of Agricultural Research. A number of assistants have helped in the raising of the plant material, establishment of the experimental plantations and collecting the data. Of these, the assistance of Messrs M. Jeevan Rao, C. Bhujanga Rao and K. Rajahapanaiah deserve special mention. Sri. S. N. Venkatraman's help in suggesting the analysis and presentation of a part of the data is also gratefully acknowledged.

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A REMARKABLE WILD HOST PLANT OF THE COTTON STEM WEEVIL, *PEMPHERES AFFINIS* FST., FROM SOUTH INDIA, AND ITS PARASITIC ASSOCIATES

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(Received for publication on 18 May 1938)

(With Plates XXII-XXVII)

Introduction

THE alternate food plants of *Pempheres affinis* have recently been receiving some attention primarily with the object of finding any new and promising parasites. Investigation prior to the inception of the present studies had largely tended to discount the importance of this aspect of study. This is evident from a statement in one of the latest publications on the subject [Dharmarajalu, 1934] namely, that the ' insect is unable to breed, leaving a few *Corchorus* plants, on any plant other than cotton.' Data in support of this conclusion were, however, lacking. On the other hand, an earlier publication [Ballard, 1922] has furnished a fair number of plants under the head. In the face of these conflicting opinions, a systematic survey though limited to the immediate neighbourhood of Coimbatore was carried out for very nearly a year. In the course of such a survey, numerous cultivated plants and weeds growing in and around cotton fields have been repeatedly examined month after month and the data gathered served to bring to light a large number of food plants. Many of the plants noted, freely admit of profuse breeding of the weevil and a few constituted new records. The infestations in some were so heavy, varied and widespread* that the problem gradually acquired a new interest. The search was therefore recently extended to a few adjoining localities including a few hill tracts and forest areas far away from cotton cultivation. This extended survey has resulted in bringing into prominence, among others, one particular species of food plant, namely, *Triumfetta rhomboidea* which forms the subject of this short paper. This species has revealed a phenomenally high percentage of weevil infestation and parasitism. Though *Triumfetta* sp. has been previously listed among food plants [Fletcher, 1919 ; Ballard, 1922], the species *rhomboidea* was for the first time observed by the writer to harbour this weevil during January 1937 when a small collection was made in Telugupalayam in the vicinity of Coimbatore.

The plant and its distribution

Triumfetta rhomboidea Jacq.—Tiliaceae (Tamil *adai otti*, Hindi *chikti*, Plate XXII) is a common herbaceus undershrub widely distributed in the

* A comprehensive account of all such plants is reserved for a future publication when matter becomes ripe for the same.

hills and plains throughout the tropical and sub-tropical India from the Himalayas to Cape Comorin ranging up to an elevation of 4,000 feet. In this province it enjoys a fairly even distribution in all the districts as seen from the collections in the herbarium.* The plants generally lie scattered among a varied vegetation and occur in very diversified situations. The species has been noted to be a common inhabitant of uncultivated waste places, weed areas near villages, along river and canal banks, outskirts of coconut and arecanut topes, borders of fields, fencings of gardens and compounds, roadsides and extends to forest regions and hill slopes. It seldom grows over three or four feet in height and has been taken from all localities in the vicinity of Coimbatore within a radius of seven or eight miles, such as Telugupalayam, Vedapatti, Vadavalli, Perur, Mathampatty, Chittraichavadi, Kuniammuthur, Singanellore, Thondamuthur, etc. Large collections have been occasionally made from distant places like Irittupallam, Siruvani hills, Thadagam and Dhoomanur, Kallar, Wallayar and Dhone valley (Malabar). The species cannot be considered to be of any great economic importance. Previous literature lists *Triumfetta* sp. among alternate food plants. But no data of any kind in regard to the exact species, locality, nature and extent of infestation or its parasitic fauna are available. Such data are highly important and necessary, particularly because another common species of the genus, namely, *T. rotundifolia* even more widely distributed and abundantly met with everywhere, on repeated examination, has been found to be singularly free from infestations.

Mode of attack and nature of habitat

Pempheres infestation in this plant has been repeatedly observed to be so severe that there seems to be ample justification in considering it as the most favourite food plant. The nature of the plant and the nutrition afforded largely determine its attractiveness to the insect besides having an important bearing on its development and multiplication. The attack here is not restricted, as in other plants like cotton, to any particular parts of the plant like the hypocotyl region but is more or less uniformly distributed throughout all portions of the herb from the upper portions of the roots, along all regions of the stem extending to even secondary branches with the exception of very slender ones lacking in the requisite minimum thickness (say less than 2 mm.). No doubt the age and size of the plant and the nature and thickness of the stem, to some extent, govern the heaviness of infestation. It is generally the older plants that are more heavily attacked, the younger ones showing comparatively lighter infestations. In these plants, particularly older ones, numerous stages representing every developmental instar are met with simultaneously, demonstrating that the plant is acceptable as food for successive generations. It also shows that considerable overlapping of broods takes place and heavy populations are rapidly built up by continuous multiplication. The density of population in the species seems to grow until its maximum capacity is overreached and the plant is killed by sheer abundance of attacks. Though apparently there is a general similarity in the method of

*The writer is indebted to the Systematic Botanist's section for the identification of this and several other species.

attack in this species and cotton, a few marked divergences in some particulars may be noted. Some minor deviations may be noted even in the matter of oviposition. The eggs are not much sunk in the bark but are nearer the surface than in the case of cotton, probably due to the fact that the bark here is comparatively much thinner. The newly hatched minute grub first mines encircling the stem or branch for a short while but quickly migrates into the deeper woody tissue and consistently resides and tunnels in the central pith region where it eventually transforms itself into a prepupa and pupa. This is greatly facilitated by the somewhat succulent and fleshy character of the woody tissue as well as the comparative softness of the stem which is pithy though not hollow. The food value and nutrition afforded appear to be extremely conducive as evidenced by the healthy and robust nature and large sizes of several instars. The grubs are creamy white, robust, and active with strong dark brown mandibles. The prepupae and pupae are proportionately bulkier. The adults developed appear to be giants in comparison with those in cotton or other food plants and are occasionally a shade darker. Oviposition also seems to be profuse as seen from a few trials. The mechanical damage caused to the host plant is certainly greater but the repair and recuperation effected by the plant is quicker as seen from the numerous large-sized galls developed in all parts of the plant including branches. That the weevil develops successfully and emerges with ease may be evident from the fact that the stem and branches are literally covered and riddled with conspicuous and large adult emergence apertures. As large a number as 127 galls and 180 emergence apertures has been recorded on a single plant in September 1937.

Comparison with other food plants

The weevil has been observed during the present investigation to breed in a number of other plants such as *Sida acuta*, *Sida rhombifolia*, *Sida glutinosa*, *Corchrus olitorius*, *Urena lobata*, *Hibiscus vitifolius*, *Malvastrum coromandelianum*. Cultivated plants include *H. esculentus*, *H. cannabinus*, and *Althaea rosea*. In none of these including its primary host, cotton, has the insect been noted to increase to the extent usually found in *T. rhomboidea*. Among these a species of *Sida* requires special mention. *Sida acuta* occurs often in similar situations and associations as *T. rhomboidea* and is comparatively widespread. There is considerable similarity between the two species in the mode of attack and course of tunnelling in that the stages are met with in the greater portion of the stem and migrate into the central region of the stem, but it cannot stand comparison with *T. rhomboidea* either in degree of infestation, hugeness of population, in the sizes of stages or in the extent of parasitism. The plant is much more woody and hard and the stages do not find it suitable for growth and emergence. Either the attack is less severe or enormous mortality and elimination of stages occur in this host. Galls are rarely developed and emergence apertures much fewer. The grubs are very often lean, discoloured being pinkish or dusky and a proportion inclusive of adults is found dead *in situ* apparently unable to emerge. In point of size of stages the only other plant that nearly approaches *T. rhomboidea* is *H. cannabinus* but the percentage of attack in this case is very low.

Ecological features of the habitat

With the present knowledge based on a limited survey of its distribution and infestation, a comprehensive discussion of the environmental characteristics of the habitat cannot be attempted. The infestation has been no doubt observed in a fairly wide range of situations and a variety of conditions. It has been noted though in varying degrees, alike in places with moderate rainfall like Coimbatore and suburbs and others with excessive rainfall such as Wallayar and Dhone valley in Malabar. It occurs also in great elevations like Siruvani and Mankarai. In drier tracts, infestations are confined to shady, damp localities along water courses or similar moist situations. One general observation that emerges from the studies is that moisture plays an important part in the occurrence and abundance of the weevil infestations, whatever may be the divergences in other features climatic, physical or biological.

Intensity of infestations

Observations recorded for the last ten months from a variety of localities serve to illustrate the extent of infestation, population densities and seasonal variations. It is never evenly or uniformly distributed in all localities. Much variation occurs even in plants taken from different situations in the same locality. Striking differences exist in plants from the same situation in accordance with variation in age and size of the plants. The general rate of infestation for the past ten months oscillated between 42 and 100 per cent averaging about 77 per cent for the entire period. Places like Thondamuthur and Irittupallam have shown consistently high percentage in infestations as well as parasitism. More striking are the data obtained regarding the populations for a locality or for an individual plant. From data recorded for the last two years for cotton, the average population has seldom risen over four or five per plant even in heavily infested fields. Whereas *T. rhomboidea* has often displayed as high a number as ten or more individuals per plant. Judging from the egg-laying capacity of the weevil (a maximum of

TABLE I

Months (1937)	No. of plants examined	Total number of infestations	Per cent infestations	Weevil population per 100 plants
January	12	84	50	525
February	4	88	100	1,000
March	31	251	42	245
April	13	134	100	385
May	6	61	100	483
June	6	26	83	50
July	41	241	56	229
August	29	416	69	917
September	36	841	92	1,017
October	27	687	77	748

121 per female) the biotic potential is not very high. Other environmental factors remaining constant any marked variations in the insect population, therefore, may be governed by the suitability of the host species. Weevil population data recorded for this plant, therefore, indicate a high preference for this plant species. Table I presents the percentage infestation and populations per 100 plants noted in Coimbatore and its environs for the last ten months.

All localities so far explored have shown appreciable infestation though the severity of attack varied in different localities. One of the reasons for such variations may be attributed to the relative abundance or scarcity and scattered nature of the distribution of the food plant. Localities like Dhone, Wallayar and Kallar where large patches of the plants are seen to occur in certain situations, showed that the populations get more evenly distributed. Table II below provides data in relation to different localities.

TABLE II

Locality	No. of plants examined	Total No. of infestations	Per cent of infestations	Weevil population per 100 plants	Remarks
Kuniamuthur	31	403	94	423	September 1937
Thondamuthur	28	623	82·5	606	
Mathampatty	9	819	66·7	2,078	
Alanthurai	19	240	68·0	226	
Siruvani	12	168	100·0	458	
Thadagam	25	122	86·0	652	February 1937
Dhone	15	45	100·0	93	
Kallar	65	31	16·9	21	November 1937
Irruttupallam	38	844	92·0	616	October 1937
Kuniamuthur	37	149	60·0	133	
Singanellore	7	119	100·0	657	
Thenamanur	12	486	100·0	1,333	
Thondamuthur	48	1,420	100·0	702	
Siruvani slope	7	125	100·0	529	
Siruvani uphill	17	24	41·0	37	
Dhone	412	424	17·0	27	
Wallayar	214	527	59·0	42	

The infestation in individual plants within the same locality or situation varied so greatly that a general average figure of percentage of attack or live population fails to convey any accurate idea of the capacity of this species to harbour heavy population. The following table presents data on the maximum number of infestations carried by individual plants during each of the past ten months. The composition and representative character of the live populations may also be noted from the table.

TABLE III

Months 1937	Maximum number of infestations in a single plant	Young grubs	Medium grubs	Mature grubs	Pre-pupae	Pupae	Adults	Maximum live population in a single plant	Remarks
January .	26	2	3	8	3	1	2	19	The collections were small. Search was not thorough and was confined to the immediate surroundings.
February .	49	1	3	13	...	3	...	20	
March . .	65	5	1	5	...	1	...	12	
April . .	22	6	...	2	...	3	...	11	
May . .	21	3	5	3	...	...	1	12	
July . .	46	6	5	3	...	2	4	20	
August . .	98	8	7	29	4	10	8	66	
September .	523	12	26	50	6	11	5	110	
October .	359	12	24	31	3	4	5	79	From 2 localities in the same month.
October .	342	11	39	41	3	2	...	96	

PARASITISM

This plant has provided the bulk of the weevil parasite material not collected in cotton. There are about seven species belonging to Braconidae and Chalcidoidea besides a parasitic nematode which definite y parasitize the weevil in this plant. The majority of these parasites (all except one species) are absent at present in cotton areas and constitute new records on *Pempheres*. All are primary in character and confine their attention to weevil larvae, particularly the mature grubs. In this connection, the absence of any species parasitizing the prepupae and pupae is keenly felt since such stages, being found in the deeper tissues of the stem and well protected, are little affected by other factors. Earlier stages such as eggs and grubs being very delicate and sensitive to desiccation are naturally eliminated to some extent by various ecological factors. No hyperparasites have so far been noted. There is one species among these which is endophagous. Some of these parasites seem to be efficient provided they can be successfully introduced in cotton areas. Their utility will depend upon their ability to establish, multiply and spread in the new habitat of cotton fields. This aspect of the problem is a new development and appears to be full of promise.

The rate of parasitism varied considerably in different regions. A maximum percentage parasitization of 14·5 for the entire area has been recorded but certain situations in the same locality showed a much higher rate. One plant for instance from Mathampatty having about 110 live stages yielded 27 parasites which works up to 25 per cent parasitism.

PARASITIC FAUNA

The following species have been noted to be parasitic on *Pempheres* in association with this food plant :—

Chalcidoidea

1. *Dinarmus coimbatorensis* Ferr.
2. *Entedon pempheridis* Ferr.
3. *Bruchocida orientalis* Crawf.

Braconidae

4. *Spathius labdacus* Nixon
5. *Spathius critolaus* Nixon
6. *Rhaconotus cleanthes* Nixon
7. *Rhaconotus menippus* Nixon

Among these, *Bruchocida orientalis* and *Rhaconotus menippus* may be considered as of very little importance, since each of these species has been encountered not more than once in association with this food plant, during the entire period covered by these studies. The following account, therefore, mainly centres round the remaining five species.

TABLE IV

Seasonal occurrence of the parasites

Parasite species	April	May	June	July	Aug.	Sept.	Oct.	Nov.
1. *Dinarmus coimbatorensis*	2	2	...	7	5	8	14	11
2. *Entedon pempheridis*	...	...	...	...	22	103	73	51
3. *Spathius labdacus*	...	...	...	...	...	16	26	24
4. *Spathius critolaus*	...	2	...	...	1	2	2	...
5. *Rhaconotus cleanthes*	...	...	...	...	...	...	4	1

The degree of parasitism by any one of the species varies considerably in the different localities or in different situations in the same locality. The table above furnishes data on the proportion of the various species during the period from April to November 1937. Among these there is only one species namely *Spathius critolaus* that occurs in cotton fields. It has been also taken from other food plants like *Sida acuta*, *Corchorus olitorius*, and *Malvastrum*. *Dinarmus coimbatorensis* seems to be associated with a number of alternate food plants, having been recorded from *H. esculentus*, *Sida acuta*, *C. olitorius*, *H. ficulneus*, *H. vitifolius*; and *Malvastrum*. *Entedon pempheridis* has been recovered also from *C. olitorius* and *Sida acuta*. *Spathius labdacus* seems to be confined to only *T. rhomboidea*.

Dinarmus coimbatorensis Ferr. (Plate XXIII).—The adult female is a dark green, thickset Chalcid with an elongate abdomen varying in length from 2·5 mm. to 5 mm. and the male with a large yellow spot at base of abdomen varies in length from 1·5 mm. to 3 mm. Ferriere [1939] has recently described the species.

This species may be distinguished from all other known species by the combination of the following characters : the medially incised clypeus, the punctate propodeum without median carina, the brown ring at base of hind tibiae and the elongate abdomen.

This species is primary and ectophagous in character. It is a larval parasite with a partiality for full-grown host grubs. The parasite has since been successfully bred in the laboratory on *Pempheres* grubs provided in cotton stalks. It occasionally oviposits in captivity but is very slow and erratic in this regard. Eggs (Plate XXIII, fig. 2) are laid singly on any part of the host after partial or complete paralysation. In one case as many as six eggs were seen laid on a single host grub within an interval of 30 minutes by a female during mid-day. The egg measures about 0·6 mm. in length. It is somewhat oblong-ovate with one end feebly produced. The surface is uneven and has a sculptured appearance being covered by very minute spines. Partheno-genetic reproduction has been noted to occur in this species. The pre-oviposition period ranged from 4 to 35 days in captivity. The larva

Triumfetta rhomboidea—typical heavily infested plant

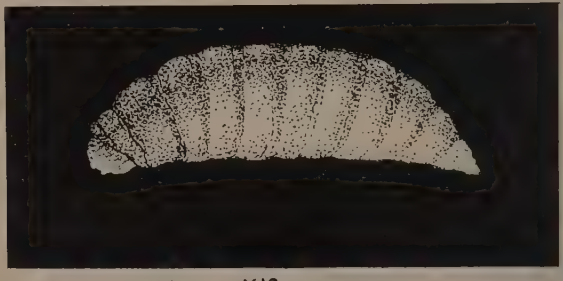
Dinarmus coimbatorensis Ferr.

×12

FIG. 1. Adult female

×85

FIG. 2. Egg



×18

FIG. 3. Full-grown larva

×18

FIG. 4. Pupa

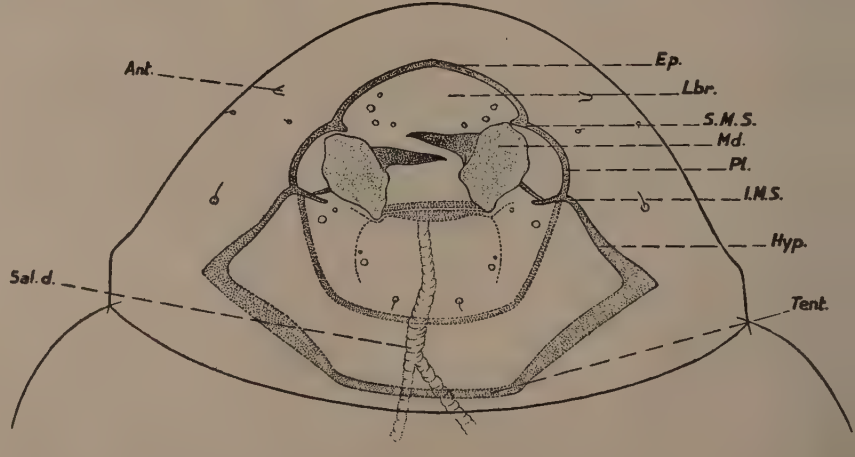


FIG. 5. Head and mouth-parts of full-grown larva

[Ant.=antenna; Ep.=epistoma; Hyp.=hypostoma; I.M.S.=inferior mandibular strut; Lbr.=labrum; Pl.=pleurostoma; S.M.S.=superior mandibular strut; Tent.=tentorium; Sal. d.=salivary duct.]

completely consumes the host grub and assumes a robust rounded body with a distinct brownish head before it transforms into a prepupa (Plate XXIII, figs. 3, 4, 5). It has also been recovered from *Pempheres* infesting several other alternate food plants as also from *Hypolixus truncatulus* in amaranthus. It is absent from cotton fields. The life-cycle varies from 17 to 21 days made up of one or two days as egg, six to eight as larva, one to three days as prepupa and 10 to $10\frac{1}{2}$ days as pupa. Adult longevity reached a maximum of 42 days averaging 23 days for four individuals with a daily supply of honey solution or raisin as food. In a proportion of cases, adults have been noted dead *in situ* in stems and pupae fail to develop into adults particularly in *Sida acuta*. The species has been collected from Malabar, Wallayar, Thadagam, Coimbatore and Siruvani. Since the species attacks *Pempheres* in cotton stalks in cages, there seems to be no reason why it should not establish itself in cotton fields.

Entedon pempheridis Ferr. (Plate XXIV).—This is a metallic blue and green Chalcidoid with an average length of 2·5 mm. ut varying from 1·5 mm. to 3·5 mm. in length. The species has been recently described by Ferriere [1939].

This species has been the most numerous among the parasites from alternate food plants. The species has been taken in small numbers occasionally from other plants like *C. olitorius*, *Malvastrum coromandelianum* and *Sida acuta*. It has been also noted to parasitize, to a small extent, other weevil grubs like *Apion* sp. in *C. olitorius*, *Lobotrachelus* in *Hibiscus manihot*. A single male specimen has been recovered from *Hypolixus truncatulus* in amaranthus. It is totally absent in cotton fields. It enjoys a wide distribution having been collected from Malabar, Wallayar, Thadagam, Siruvani and Coimbatore and suburbs. This is also a primary larval parasite. This seems to be the only endophagous parasite so far met with in *Pempheres*. The egg, larval and a portion of prepupal stages are spent inside a full-grown host grub. The host grub is not paralysed by oviposition. It seems to be apparently healthy, normal and unaffected, and tolerably active for a day or two until the parasite larva is hatched and begins to feed on the fluid contents of the body cavity in the initial stages. As the larva grows, it begins to feed on the internal organs and the activity of the host grubs gets more and more diminished. Probably only one egg is laid in each host as not more than one parasite larva has been noticed inside a single host stage and only one adult has been seen to develop from one host. The parasite larvae have been dissected out in a number of instances in varying stages of growth (Plate XXIV). These are milky white, flattened, leaf-like until they are full grown. When they get full grown the entire contents of the host grub are consumed leaving only a thin cuticular sac-like covering. The larva grows rapidly and assumes a robust cylindrical form filling up the cuticular bag and causing it to bulge out due to pressure of the growing parasite from inside. As it develops into a prepupa, the distended and weakened cuticular covering is unable to retain it, gets dry, cracks and crumbles leaving the parasite exposed. The parasite soon pupates naked and assumes a jet black colour No trace of the host may be seen except the small hard mandibular remains. The pupal period ranges from 8 to 12 days averaging 11 days for about 40

individuals. The egg has not been noted except in a doubtful instance. The entire development has been accomplished in captivity. The duration of egg and larval period has not been accurately determined but from a few observations it may be said roughly to vary from 8 to 11 days. The egg period lasts probably only for a day. The prepupal period may extend to even three days. The adults are strongly heliotropic being found to crowd towards the end of the tube directed to sunlight. Adult longevity with raisin as food has risen up to 18 days. The extent of parasitism by the species is seen to be the highest and the parasite appears to possess considerable possibilities if only it would accommodate itself in cotton fields. As large a number as 103 individuals (consisting of 9 adults, 93 pupae and one full-grown larva) were obtained from this food plant in September 1937. A maximum number of 11 parasites has been recovered from one single plant.

Bruchocida orientalis Crawford.—There is only one solitary instance when this species was collected. This was recovered as a pupa from a mature grub of *Pempheres* in *Triumfetta rhomboidea* in Perur on 7th July 1937. This emerged as an adult female on 12 July, 1937. The adult was comparatively large sized with a dark head and metallic blue and green body. The ovipositor was fairly conspicuous with a yellow brown colour and dark tip. The female lived in captivity for a period of 21 days with a supply of sugar solution. It also paralysed about seven *Pempheres* grubs provided in cages but failed to oviposit. It has been recorded as parasitic on *Bruchus chinensis* from Bangalore.

Spathius critolaus Nixon.—This is a slender elongate reddish brown insect about 2 to 3 mm. in length with a dark abdomen and vestigial wings. Winged forms are occasionally found to occur in both the sexes but more often among females. This is a common parasite which has been recovered in association with most food plants, including cotton. It is an ectophagous larval parasite attacking mature grubs and rarely medium sized ones also. It lends itself to breeding and multiplication in captivity not only on *Pempheres* but also on such subsidiary hosts like Amaranthus weevil grubs, *Hypolixus truncatulus* and the Bostrychid borer of cotton—*Sinoxylon sudanicum*. Normally eggs are laid singly one on each host grub, after complete paralysation of the same by stinging. A maximum of 53 eggs has been recorded for a single female. It displays considerable discrimination in selecting its victims preferring healthy, active, non-parasitised host grubs. The percentage of parasitism in nature has seldom risen above one per cent in cotton fields in the most favourable season, but it paralyses more host grubs than actually oviposited upon. The total life-cycle period varies greatly according to season from a minimum of 12 days to 28 days in cooler months. The parasite enjoys a wide distribution occurring as it does in cotton and non-cotton areas such as Ramanad, Erode, Coimbatore and suburbs, Thadagam, Siruvani and Malabar.

Spathius labdacus Nixon (Plate XXV).—This is a fairly large Braconid varying very much in colour and size. All grades of colour from reddish brown to dark brown are met with. In length it varies from 3 mm. to 4·4 mm., averaging about 3·7 mm. for a dozen specimens. The species has been described by Nixon [1939].

ENTEDON PEMPHERIDIS FERR.

FIG. 1. Adult female

FIG. 2. Ist stage larva (dorsal view)

FIG. 3. Medium-sized larva (ventral view)

FIG. 4. Full-grown larva (dorsal view)

FIG. 5. Pupa (ventral view)

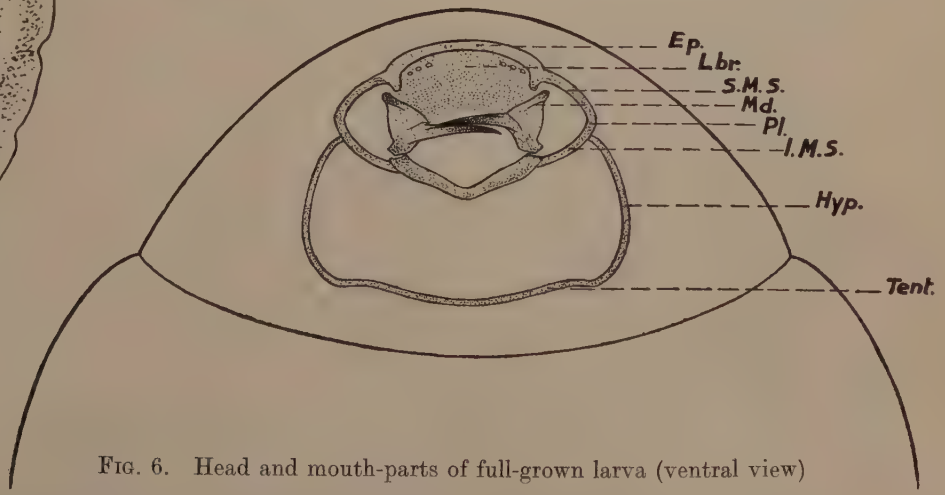


FIG. 6. Head and mouth-parts of full-grown larva (ventral view)

[Ep.=epistoma; Hyp.=hypostoma; I.M.S.=inferior mandibular strut; Lbr.=labrum; Pl.=pleurostoma;

SPATHIUS LABDACUS NIXON

Fig. 1. Adult female

Fig. 2. Egg (magnified)

Fig. 3. Full-grown larva (side view)

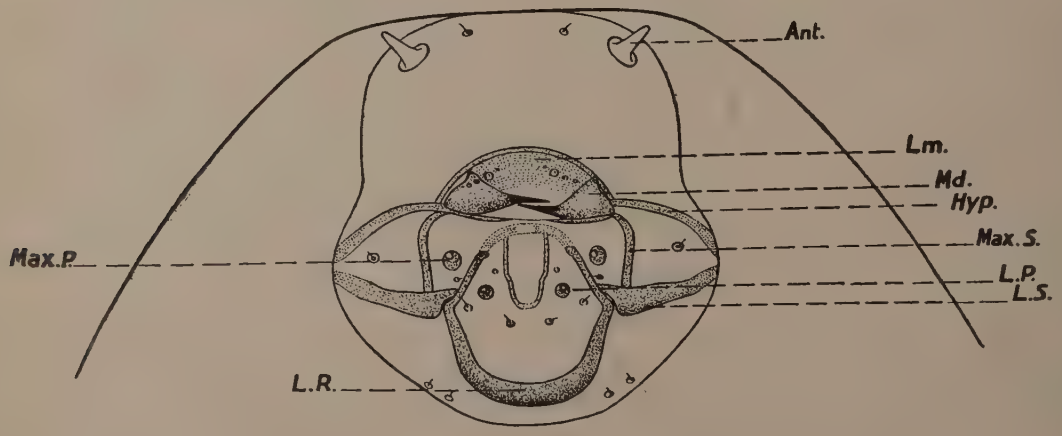


Fig. 4. Head and mouth-parts of full-grown larva

[Ant.=antenna; Lm.=labrum; Md.=mandible; Hyp.=hypostoma; Max. S.=maxillary strut; L.S.=labial strut; L.R.=labial ring; Max. P.=maxillary palp; L.P.=labial palp]

This is a winged species with a long ovipositor, the longest of all known *Pempheres* parasites. This was for the first time taken in September 1937, when about 16 individuals were recovered either as larvae or as cocoons. In October as many as 26 have been obtained. It has been successfully bred in the laboratory and the life history more or less elucidated. It is a larval primary ectophagous parasite. It prefers healthy non-parasitised, full-grown host grubs and lays one egg (rarely two) on any part of the host body after it is rendered inactive by complete paralyzation. The egg (Plate XXV, fig. 2) is translucent elongate, cigar shaped and curved with extremities rounded. The cephalic end is much broader than caudal end. A maximum of two eggs has been noted per day per female. The egg-laying capacity in captivity has seldom risen over ten per female in cages. Parthenogenetic reproduction is fairly common, the resulting progeny being invariably males. The preoviposition period ranged from 3 to 12 days ordinarily and in some cases seemed to be considerably prolonged particularly in parthenogenetic cases where a maximum of 33 days has been recorded. Incubation period varied from 1 to 2 days averaging 1·4 days for 11 cases. Larval period varied from 4 to 6 days averaging 4·4 days for 11 cases. The full-grown larva (Plate XXV, figs. 3, 4) which is robust having clearly marked prominent urate cells, spins usually a cocoon before pupation. The prepupal and pupal periods ranged from 13 days to 16 days averaging 14 days for 8 individuals. The prepupal period alone ranged from 2 to 3 days averaging 2·3 days for 4 cases. The total life-cycle period varied from 17 to 22 days according to the season and fluctuations in temperature. The life period was seen prolonged in cooler months, namely November to February. The males have a slightly shorter life-cycle period than females, averaging 21 days for females and 19 days for males. The adult longevity reached a maximum of 73 days with honey solution or raisin but averaged 61 days for 5 individuals. This seems to be one of the most promising species. It is a large winged species and has greater potentiality than the smaller wingless *Spathius*. Above all it has a much longer ovipositor which can pierce and penetrate deeper into the stem and grubs which have tunnelled even into the central regions of the stem become accessible to the species. It has been recovered so far only in association with *Triumfetta rhomboidea*. It remains to be seen if the same will adapt itself to the environment of cotton fields.

Rhaconotus cleanthes Nixon (Plate XXVI).—This is a reddish brown Braconid varying in length from 2·2 to 4·5 mm. Nixon [1939] has described the new species.

This slender winged Braconid with an average length of 4 mm. has been recovered from *Triumfetta rhomboidea* during October 1937. Only a few cases of parasitism by the species in this food plant have come to the notice. The species has also been occasionally noted and taken from the same insect host from *Sida acuta* in Dhone and Kuniamuthur. It lends itself to artificial breeding in captivity to a certain extent. This is also a primary larval ectophagous parasite. It prefers only mature host grubs. Oviposition is very infrequent and erratic. The egg (Plate XXVI, fig. 2) is narrow, translucent with caudal end narrower than head end. The full-grown larva (Plate XXVI, figs. 3, 4) is elongate and slender with a brownish white

colour. The life cycle occupies from 16 to 24 days. The minimum pre-oviposition period is about 2 days but varies considerably. The egg period ranges from 1 to 2 days ; larval period from 4 to 6 days. A maximum capacity of 15 eggs has been noted for a single female. The adult longevity runs up to 30 days with raisin.

Rhaconotus menippus Nixon (Plate XXVII).—This is a decidedly darker species than the previous one and is of an average length of 3 mm. Nixon describes the species as being characterised by the division of tergite (2 plus 3) into three areas and by having the middle one of these areas differently sculptured from the other two. The fine striation surrounding the ocelli is also likely to be specific.

This parasite has been recovered only once parasitising *Pempheres* in association with this food plant. More often it has been noted to parasitise this weevil infesting another food plant, namely *Corchorus olitorius*. It has been also taken on several occasions as a parasite of another weevil, *Hypolixus truncatulus* in amaranthus. The general life history is similar to that of *R. cleanthes*.

Nematodes

Geomermis indica Steiner.—This Mermithid was for the first time discovered to be parasitic in mature *Pempheres* grubs infesting this plant host during September 1937. These have been, later occasionally taken from the same material from the same locality, namely Thondamuthur, during October and November. Apparently its range of occurrence is limited to this locality since it has not been encountered in materials from a few other places. In a few instances, these worms have been recovered also from later stages of the host insect such as prepupae and pupae.

The parasitized host grub does not show any marked external indication. The only differences that may sometimes be noted consist in the grub being inactive and swollen or discoloured. In one or two instances the emergence of the larval forms by forcing through the weakened body wall has been actually observed. Rarely also, the swollen abdomen of the host grub showed external curved ridges and grooves indicating the presence of the much curled worms inside.

These larval forms are dirty white, slender, thread-like worms less than $\frac{1}{2}$ mm. in length found in some numbers inside the body cavity of the host. In a single instance an actual count was made and eleven such forms were noted. These are, when mounted in a drop of distilled water on a slide, found to be motionless for a while but soon become active with wriggling and lashing movements. Through the kindness of Dr Steiner, Principal Nematologist, Washington, the worms have been identified as belonging to a new species—*Geomermis indica*. The genus *Geomermis* itself is said to be new and has not been described. According to Dr Steiner these forms are Mermithids without cross fibres in the cuticle, with eight longitudinal chords and six cephalic pupillae with a short semi-spherical vagina and with very short paired spicula. The few forms known in the genus are confined to the U. S. A. This forms the only record of the genus from outside that country. This is the first record of nematode parasitism in *Pempheres* and probably also in stem boring Curculionidae.

FIG. 1. Adult female

FIG. 2. Egg

FIG. 3. Full-grown larva

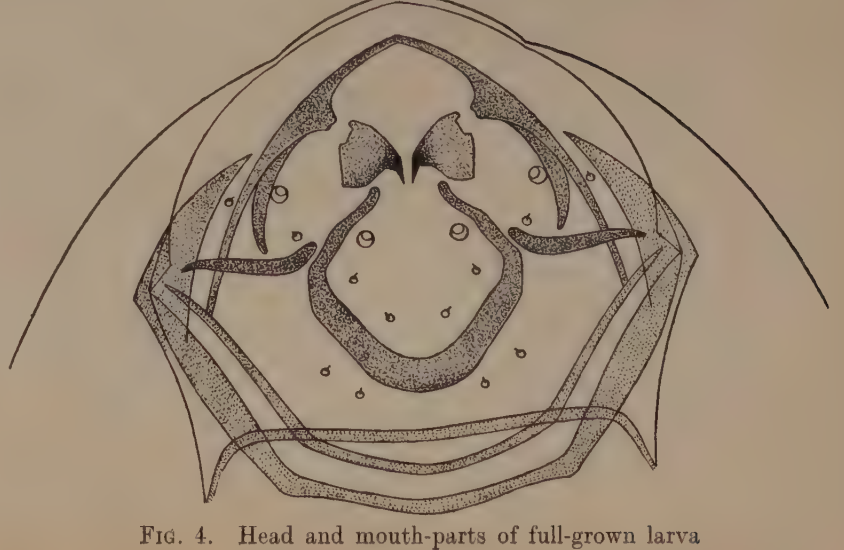


FIG. 4. Head and mouth-parts of full-grown larva

RHACONOTUS MENIPPUS NIXON

Adult female

The method of infection is not definitely known. Since these have been encountered only in the rainy season in October and November it may be that rain stimulates the female parent to ascend up these plants and penetrate the cracks, crevices and grub tunnels in the stem where eggs are laid. The host grub gets infested while feeding on plant tissue. It may also be that the larva that hatches pierces the body wall of the grub and occupies the body cavity. With the present state of our knowledge the economic significance of this phenomenon cannot be truly assessed. As factors of control. these may be at present regarded as of little importance.

Significance of infestation and parasitism in the food plant

Great stress has been recently laid by eminent authorities on the study of alternate food plants with a view to discover the primitive wild association of indigenous insect pests in any biological control project. Weeds and wild host plants were not seriously reckoned hitherto as hosts of this weevil. The few weeds which were noted to harbour the weevil in and around cotton fields were dismissed as of no importance except as probable minor nuclei for reinfestation of cotton crops. As for parasites, these were practically unknown from this source. The present studies have served to dispel such notions and have given a new orientation to the biological control of this insect.

Pempheres affinis is a polyphagous species and attacks a number of wild plants in a wide range of conditions. Incidentally this polyphagy constitutes a serious handicap in breeding resistant varieties. Further, the weevil appears to be a normal inhabitant of many regions beyond the limits of cotton cultivation. Profuse breeding of the weevil in a wild host plant like *T. rhomboidea* in virgin forest areas and the variety and comparative abundance of parasites in such haunts are of considerable significance. The majority of such parasites being absent in cotton fields is also a feature of importance. The ability of some of these to parasitise the weevil in different host plants is another eminently desirable feature. A thorough knowledge, therefore, of these parasites in relation to the weevil and its host plant appears to be essential for judging the possibility of utilisation of these species. Hence the necessity for an extended and elaborate examination of these alternate food plants is clearly brought out by these studies.

In a previous paper [1937] it has been suggested by the writer that the weevil might be indigenous to India by reason of its occurrence in *bhindi* in diverse situations far away and completely cut off from cotton cultivation, such as Dehra Dun in the United Provinces, Manantoddy hills in Malabar, etc. The present studies have served to emphasise this aspect and provide additional proof in support of this inference. This additional evidence seems to leave no room for doubt as to its place of origin since it would be otherwise impossible to explain the presence of such separate infestations in varied regions including sylvan associations and forest areas such as Siruvani, Wallayar forests, Kallar and Dhone hills in Malabar. The case of weeds and plants found in and near cultivated regions is quite different and is easy of interpretation as the infestations could have proceeded from cotton. The evidence in favour of the weevil's primitive association with *bhindi* still holds good but this plant

is at present a cultivated one though originally wild. Recent studies, therefore, raise the question whether such wild plants like *T. rhomboidea*, *Sida acuta*, *S. rhomboidea*, *Urena lobata*, etc. may not have had an earlier association with the weevil. Among such plants *T. rhomboidea* stands unique both in respect of heaviness of infestation and high rate of parasitism. In any attempt, therefore, in classifying the more important of the known food plants according to their length and primitiveness of association with the weevil, cotton will have to be ranked as recent, *bhindi* as having an older association and *T. rhomboidea* as having a still more primitive relationship with the pest. For quite another reason also cotton does not appear to constitute its natural food plant because its normal development in this host is arrested and great mortality is caused by such inherent factors as gumming. From a few trials in the field and in the laboratory the oviposition of adults bred from *Triumfetta* has been found to be poor in cotton. On the other hand oviposition of cotton-bred adults on *Triumfetta* stalks has been slightly better. Transfer of different stages of grubs from one plant to the other does not affect their development. These experiments in their behaviour suggest that *Triumfetta* may perhaps be its original food plant. Anyway, there seems to be little doubt that *Triumfetta rhomboidea* is the most preferred among its known food plants. The practical importance of these observations is the opening of a new avenue of investigation, namely the possibility of manipulation and liberation of suitable parasites from this source for colonization in cotton fields. A small though unconscious step in this direction has been started by the breeding section by the importation of this material for artificial weevil infestation of cotton crop in the breeding station. But systematic and planned attempts to encourage successful emergence and liberation of such parasites in conjunction with laboratory breeding, if and when necessary, seem to be full of promise.

ACKNOWLEDGEMENTS

The writer wishes to record his grateful thanks to the Indian Central Cotton Committee for providing the financial assistance and the Cotton Specialist for affording facilities for the studies. He is also thankful to fieldman Mr S. Royappan, who helped in the field collection of plants during the beginning of this study and Mr Tobias, who continued it. Thanks are also due to Fieldman Mr N. Muthuswami for assistance in preparing the tables. The writer is greatly indebted to Sir A. K. Guy Marshall and the specialsts of the Imperial Institute of Entomology for identification of weevils and parasites.

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STUDIES ON THE ROOT-ROT DISEASE OF COTTON IN THE PUNJAB

VIII. FURTHER STUDIES ON THE PHYSIOLOGY OF THE CAUSAL FUNGI

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(Received for publication on 23 October 1939)

Introductory

IN view of the great losses to the cotton growers due to root-rot disease, the importance of the disease in the Punjab cannot be over-emphasized. The study of the physiological behaviour of the causal fungi *Rhizoctonia bataticola* = C. strain of Haigh = *Macrophomina phaseoli* and *Rhizoctonia solani* is of great importance in the discovery of the control measures for the disease.

The intensity and severity of attack of these fungi largely depends on the environmental conditions which, if favourable, tend to increase their activity. The kind of food, moisture content of the soil and temperature may accelerate their virulence.

The fungi under consideration are able to attack a considerable range of host plants and are not highly selective in their metabolism so much so that all the carbohydrates and nitrogen sources tested [Vasudeva, 1937] yield satisfactory growth.

These fungi do not show any appreciable growth under highly anaerobic conditions. Their growth is markedly retarded at 25 per cent concentration of carbon dioxide. Though the growth is arrested at higher concentrations of carbon dioxide yet the fungi are found to be viable even after prolonged exposure to highly anaerobic conditions when normal conditions are restored [Vasudeva, 1936]. Experiments have been conducted to determine whether different carbon compounds would support satisfactory growth under anaerobic conditions.

Material and methods

The two fungi used in this investigation were :—

Rhizoctonia bataticola (Maubl.) Ashby. = C. strain of Haigh = *Macrophomina phaseoli*	Isolated from diseased cotton roots.
Rhizoctonia solani (Kuhn. group)	Isolated from diseased cotton roots.

At the beginning of the work the purity of the cultures was ensured by taking a single hyphal tip in each case, after the method described by Brown [1924]. Stock cultures of the fungi were maintained in tubes of potato extract agar. The inocula for cultural work were invariably taken from cultures 10 to 20 days old.

The fungi were grown in liquid and on agar media containing the same ingredients and a single carbohydrate.

The following media, with or without agar, were employed :

1. Potato extract :—

Peeled potatoes	20 gm.
Agar	20 gm.
Distilled water	1,000 c. c.

2. Cotton root synthetic [Vasudeva, 1937] was used as basic medium. The nitrogenous constituent, peptone, normally used in this medium was replaced by ammonium sulphate calculated to yield an equivalent amount of nitrogen. And carbohydrate constituent was reduced to half the normal strength.

The composition of the medium as used in the experiments described in the present paper was as follows :—

Carbohydrate	10 gm.
Ammonium sulphate	2·16 gm.
K_2PO_4	1·9 gm.
$MgSO_4$	0·4 gm.
NaCl	0·6 gm.
$FeCl_3$	A trace.
Bromcresol purple (1 per cent)	1 c. c.
Bacto agar	20 gm.
Distilled water to make up	1,000 c. c.

The carbohydrates used were as follows :—

Maltose, glucose, sucrose, lactose, galactose, dextrin and soluble starch.

The media were divided into 40 c. c. lots unless otherwise mentioned in test tubes or Erlenmeyer's flasks of uniform size and capacity. Flasks of 125 c. c. capacity and test tubes 25 × 200 mm. and of 90 c. c. capacity were used throughout the course of these experiments.

The *p*H of media in all cases was brought to the neutral point, using bromcresol purple as indicator. Inoculations were made from cultures with active growth and as far as possible uniform size of inocula were introduced. Observations were made as to the time required for the acidification of the media and the amount of growth. Colour change of the medium from red to straw yellow colour, indicated the acidification of the medium, i.e. from *p*H 7 to approximately 5.

The experiments were conducted both at laboratory temperature and at 30°C.

Cultures grown on the agar medium were mostly surface growths, and were therefore exposed to the varied experimental conditions. Those grown in the liquid media were almost always submerged, except when the inocula were kept suspended on the surface of the medium by means of platinoid wire basket like structures.

Experimental results

(*a*) *Growth of* R. solani *and* R. bataticola *in liquid and agar media with different carbohydrates.*—The fungi were grown both in flasks and test tubes containing liquid and agar media. The test tubes with liquid media were placed upright in desiccators and arranged in such a manner that observations could be made without touching them as slight shaking or movement of the tubes would upset the growth in the liquid media. Results of typical experiments for *R. solani* and *R. bataticola* are summed up in Table I.

The results show that both in the liquid and agar media all the carbohydrates tested supported a fairly satisfactory growth and that the acidification of agar cultures occurred earlier than the liquid media. These results hold good both for tube and flask cultures. The inocula in the case of liquid media were submerged whereas in the agar media these were on the surface.

In the case of agar cultures in test tubes a beautiful yellow ring was formed along the upper surface of the medium. The breadth of the ring depending upon the depth to which the fungal hyphae had penetrated. A scanty and sparse growth was noticed in the control media lacking in carbohydrate constituent.

It was observed during the course of these experiments with *R. bataticola* that the colour change or the acidification was delayed in liquid media but did not occur at all in agar media when lactose or galactose were used as source of carbon.

The experiments were repeated a number of times at the room temperature as well as at 30°C. and results similar to the above were obtained.

(*b*) *Submerged and floating cultures.*—During some cultural experiments with liquid media in the laboratory it was observed that there were differences in the amount of growth and time required for acidification or colour change in the same set of flasks. Such variations appeared to be due to the position of the inocula. Experiments were, therefore, carried out to determine the effect of submerged and floating inocula on the growth and the time required for acidification of the cultures.

Fifty c. c. of the basal liquid medium, i.e. modified cotton root synthetic was put in Erlenmeyer flasks of 125 c. c. capacity. In the flasks containing the media platinoid wire loops were inserted through the plugs and suspended in such a manner that the loops just touched the central point on the surface of the medium. The flasks with media and loops were sterilized as usual and divided into two equal lots and inoculated with vigorously growing cultures of *R. bataticola* and *R. solani*. In one set the inocula were placed carefully on the loops in the flasks so that the inocula were kept floating on the surface of the medium whereas in the other set of flasks the inocula were

TABLE I

Days required for acidification and comparative growth on liquid and agar media with different carbohydrates for* R. solani *and* R. bataticola

Source of carbon	*R. solani*								*R. bataticola*							
	Liquid medium				Agar medium				Liquid medium				Agar medium			
	Test tubes		Flasks		Test tubes		Flasks		Test tubes		Flasks		Test tubes		Flasks	
	Growth (9 days)	Days for acidification	Growth (5 days)	Days for acidification	Growth (7 days)	Days for acidification	Growth (4 days)	Days for acidification	Growth (9 days)	Days for acidification	Growth (5 days)	Days for acidification	Growth (7 days)	Days for acidification	Growth (4 days)	Days for acidification
Maltose	++	9	++++	6	++++	4	++++	4	++++	7	++++	5	++++	3	++++	3
Glucose	++	7	+++	6	++++	4	++++	4	++++	7	+++	5	++++	3	+++	4
Sucrose	++	7	+++	6	++++	5	++++	4	++	10	+++	5	++++	3	+++	4
Lactose	++	7	++	8	++++	6	++	5	++	10	+	No change in 8 days	++	No change	+	No change
Galactose	++	9	++	8	++++	6	++++	4	++	10	+++	8	++++	Do.	++	Do.
Dextrin	++	9	++	6	++++	4	++	5	+++	8	++++	5	++++	3	++++	3
Soluble starch	++	9	++	6	++++	4	+++	4	++++	7	++++	5	++++	3	++++	3
No carbohydrate	Slight growth	No change	+	No change	+	No change	+	No change	+	No change	+	No change	+	No change	+	No change

* At laboratory temperature.
\+ Signs denote the amount of growth; the larger the number the greater the amount of growth.

TABLE II

Acidification of cultures in relation to floating and submerged inocula

Source of carbon	*R. solani*						*R. bataticola*					
	Agar		Floating		Submerged		Agar		Floating		Submerged	
	Growth	Days for acidification	Growth	Days for acidification	Growth	Days for acidification	Growth	Days for acidification	Growth	Days for acidification	Growth	Days for acidification
Maltose	++++	4	++++	4	+++	5	++++	4	++++	5	++++	8
Glucose	++++	4	++++	4	++++	5	++++	4	++++	5	++++	7
Sucrose	++++	4	++++	4	++	6	++++	4	+	8	+	..
Lactose	+++	4	+++	5	+++	5	++	No change	+	28	+	37
Galactose	++++	4	++++	4	++	6	+++	Do.	+++	7	++	15
Dextrin	++++	4	++++	4	++	6	++++	4	++	7	+	24
Soluble starch	++++	4	++++	4	++	6	++++	4	+	10	+	22
No carbohydrate	+	No change	+	No change	+	No change	+	No change	+	No change	+	No change

inserted in the normal way and these got submerged in the medium. The inoculated flasks were arranged in an incubator at 30°C. in such a way that the observations could be made at a glance. The flasks were not moved or shifted throughout the course of these experiments in order to allow uniform and uninterrupted growth. Agar cultures in flasks were also set up for comparison.

The experiments were repeated several times and the results of a typical experiment are set out in Table II.

The data show that in the case of both the fungi the time required for acidification of submerged cultures is greater than the floating cultures. The growth in submerged cultures was comparatively slow. The cultures with the floating inocula almost correspond with agar cultures which are mainly surface growths. It is likely that the growth of the fungi in submerged cultures produces a by-product which if allowed to accumulate retards further growth. Such a by-product very likely seems to be of a volatile nature which is easily lost from surface cultures but is retained in the liquid medium in the case of submerged cultures.

It is clear from the results that the growth of these fungi is affected by the solid or liquid condition of the medium in which these are cultured and also on the position of the inoculum, i.e. submerged or floating.

The growth of these fungi is indicated as : + + + + = very good = 4, + + + = good = 3, + + = fair = 2, + = slight growth = 1 and multiplied with 100 to avoid fractions. The utilization quotient indicating the comparative availability of the food material was calculated by dividing growth × 100 by the number of days required for acidification [Moore, 1937]. The utilization quotients for agar, floating, and submerged cultures of *R. solani* and *R. bataticola* as estimated from Table II are given in Table III.

TABLE III

Utilization quotients for R. solani *and* R. bataticola *under normal atmospheric conditions*

Carbohydrate	*R. solani*			*R. bataticola*		
	Agar	Floating	Submerged	Agar	Floating	Submerged
Maltose	100	100	60	100	80	25
Glucose	100	100	80	100	80	57
Sucrose	100	100	30	100	13	..
Lactose	75	80	60	0	4	3
Galactose	100	100	30	0	43	13
Dextrin	100	100	30	100	29	4
Soluble starch	100	100	30	100	10	5
No carbohydrate	0	0	0	0	0	0

The utilization quotients are lower for submerged than for the floating cultures. In agar cultures the utilization quotients for *R. solani* almost correspond with the floating cultures but in the case of *R. bataticola* the utilization quotients are higher in agar than in floating cultures except in the lactose and galactose constituents where the quotient is lower and has fallen to zero.

(c) *Growth in various concentrations of carbon dioxide.*—The two fungi *R. solani* and *R. bataticola* were grown in test tubes on modified cotton root synthetic agar with different carbohydrates. The inoculated tubes were placed in desiccators which were then sealed. The test tubes were kept upright by sliding them singly through circular slits made in a piece of cardboard. This rendered making of observations comparatively easy. Carbon dioxide was let into these chambers by creating the required amount of vacuum with Cenco Megavac pump and by adjustment of pressure with the help of a manometer.

The experiments were conducted in atmosphere of 10, 20, 30 and 40 per cent carbon dioxide. Controls were kept under ordinary atmospheric conditions.

The results obtained by growing the fungi in different concentrations of carbon dioxide and in normal atmosphere are recorded in Table IV.

At 30 per cent concentration the growth of *R. solani* practically ceased whereas there was fair amount of growth in the case of *R. bataticola*. At 40 per cent concentration *R. solani* failed to grow but *R. bataticola* showed slight growth. An appreciable reduction in the amount of growth was noticed in the case of both the fungi even at twenty per cent concentration of carbon dioxide. The rate of growth in various concentrations of carbon dioxide was comparatively slow and the cultures took longer time for acidification than in normal atmosphere. The utilization quotients are inversely proportional to the increase in concentration of carbon dioxide.

(d) *Effect of nitrogen and oxygen.*—In another experiment the effect of nitrogen and oxygen on the growth and reaction of medium was studied. In two lots of evacuated chambers containing cultures of *R. solani* and *R. bataticola*, pure nitrogen or oxygen was let in. In another set of evacuated desiccators oxygen and nitrogen was let in the ratio of 50 : 50. Observations were made as to the growth of the fungi and the time required for acidification of the culture media was also noted. The data of such an experiment are given in Table V.

The results show that the growth and time required for acidification in the case of *R. solani* is not appreciably affected in an atmosphere of pure oxygen, but in the case of *R. bataticola* pure oxygen appears to have a depressing effect on the growth and the acidification of the medium is delayed. Pure nitrogen and nitrogen and oxygen (50 : 50) have no appreciable effect on the growth or time required for acidification of the medium in the case of either of the two fungi.

Thanks are due to the Indian Central Cotton Committee for kindly providing the necessary funds for carrying out these investigations.

TABLE IV

Days required for acidification of cultures in various concentrations of carbon dioxide

Carbohydrate	*R. solani*								*R. bataticola*							
	Atmospheric control		10 per cent carbon dioxide		20 per cent carbon dioxide		30 per cent carbon dioxide		Atmospheric control		10 per cent carbon dioxide		20 per cent carbon dioxide		30 per cent carbon dioxide	
	Growth (7 days)	Days for acidification	Growth (9 days)	Days for acidification	Growth (12 days)	Days for acidification	Growth (12 days)	Days for acidification	Growth (3 days)	Days for acidification	Growth (3 days)	Days for acidification	Growth (3 days)	Days for acidification	Growth (3 days)	Days for acidification
Maltose	++++	8	++++	10	Slight growth	No change	No growth	No change	++++	3	++++	4	+++	4	++	6
Glucose	++++	7	++++	9	Do.	Do.	Do.	Do.	++++	3	++++	4	+++	4	++	6
Sucrose	+++	8	++++	10	Do.	Do.	Do.	Do.	+++	4	+++	5	++	5	+	7
Lactose	++	No change in 12 days	+++	No change in 12 days	Do.	Do.	Do.	Do.	++	No change in 7 days	++	No change in 10 days	++	No change	+	No change
Galactose	+++	Do.	+++	Do.	Do.	Do.	Do.	Do.	++	Do.	++	Do.	++	Do.	+	Do.
Dextrin	+++	9	+++	11	Do.	Do.	Do.	Do.	++	5	+++	5	++	6	+	8
Soluble starch	+++	9	+++	11	Do.	Do.	Do.	Do.	++	5	++	5	++	6	+	8
No carbohydrate	+	No change	...	No change	Do.	Do.	Do.	Do.	+	No change	+	No change	+	No change	+	No change

TABLE V

Effect of nitrogen and oxygen on the growth and time of acidification

Carbohydrate	*R. solani*								*R. bataticola*							
	Atmospheric control		100 per cent nitrogen		100 per cent oxygen		50 per cent nitrogen and 50 per cent oxygen		Atmospheric control		100 per cent nitrogen		100 per cent oxygen		50 per cent nitrogen and 50 per cent oxygen	
	Growth (3 days)	Days for acidification	Growth (3 days)	Days for acidification	Growth (3 days)	Days for acidification	Growth (3 days)	Days for acidification	Growth (5 days)	Days for acidification	Growth (5 days)	Days for acidification	Growth (5 days)	Days for acidification	Growth (5 days)	Days for acidification
Maltose	++++	3	++++	3	++++	3	++++	3	++++	5	++++	5	++	7	++++	5
Glucose	++++	3	++++	3	++++	3	++++	3	++++	5	++++	5	++	7	+++	5
Sucrose	++++	3	++++	3	++++	3	++++	3	+++	6	++++	5	++	7	+++	6
Lactose	+++	6	+++	6	++	6	+++	6	+	No change	++	No change	+	No change	+	No change
Galactose	+++	6	+++	6	++	6	+++	6	+++	Do.	+++	Do.	++	Do.	++	Do.
Dextrin	++++	3	++++	6	++++	3	++++	6	+++	6	+++	6	++	7	++++	5
Soluble starch	++++	3	++++	3	+++	6	++++	3	+++	5	+++	5	++	7	++	7
No carbohydrate	+	No change	+	No change	+	No change	+	No change	+	No change	+	No change	+	No change	+	No change

SUMMARY

1. All the carbohydrates tested supported a fairly satisfactory growth of *R. solani* and *R. bataticola*. Agar media are comparatively more favourable for growth than the liquid media. Acidification also in the case of agar cultures is more rapid but in the case of *R. bataticola* the acidification is delayed in liquid media and does not occur at all even in agar media when lactose or galactose are used as source of carbon.

Floating cultures almost correspond with agar cultures in the rate of growth whereas in the case of submerged cultures the growth is slow and acidification of the cultures is delayed.

2. Carbon dioxide has a depressing effect on the growth and acidification of the media is delayed.

3. Effect of oxygen and nitrogen has also been tested.

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STATISTICAL NOTES FOR AGRICULTURAL WORKERS

NO. 25. A SIMPLIFIED METHOD OF ANALYSIS OF QUASI-FACTORIAL EXPERIMENTS IN SQUARE LATTICE WITH A PRELIMINARY NOTE ON JOINT ANALYSIS OF YIELD OF PADDY AND STRAW

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(With one text-figure)

Introduction

FISHER'S Randomized Block and Latin Square designs have proved very useful in agricultural field experiments, but can be adopted only when a limited number of plots, usually not greater than ten or eleven, is included in a block or row and column. This limitation on the number of treatments which can be tested simultaneously is a serious handicap in the case of factorial experiments in which the number of treatment combinations keeps on increasing with the number of factors and with the number of the levels at which each factor is tested. The devices of confounding main effects in split-plot designs and interactions among sub-blocks are used to overcome this difficulty.

Recently Yates [1936, 1] has developed another method for keeping the block size within efficient limits when the number of treatments of a non-factorial experiment becomes large. The need of such single factor experiment occurs very frequently in practice when we have to make preliminary selection from a large number of new strains of a crop. Since only a single factor (e.g. variety, in this case) is involved, the several comparisons among the treatments cannot be classified under sets of main effects and interactions. For this reason the principle of straightforward confounding is apparently inapplicable here. Yates however used the ingenious idea of using a factorizable number (say, $v = p.\ q.\ r.\ldots\ldots$) for the number of varieties, and then viewing the varieties as all combinations of several factors (non-existent though) at levels p, q, r, ..., etc., for each group. We can then divide the varieties in v/p groups of p in each group, v/q groups of q in each group, v/r groups of r in each group, and so on. The comparisons among the v/p groups in the first type of division will correspond to the main effects and interactions of all factors excluding the first pseudo-factor ; the comparisons among the v/q groups in the second type of division will correspond to the main effects and interactions of

all factors excluding the second pseudo-factor ; the comparisons among the v/r groups in the third type of division will correspond to the main effects and interactions of all factors excluding the third pseudo-factor and so on. We can then confound these main effects and interactions of the various pseudo-factors, by assigning to a block only those varieties which occur together in the same group.

If there is sufficient land each group may be replicated a number of times, which should be the same (n, say) for each group. Thus the number of blocks in the experiment will be $vn\left(\frac{1}{p}+\frac{1}{q}+\frac{1}{r}+\ldots\right)$. The block size will not be the same if $p, q, r, \ldots$ are not equal. Thus there will be vn/p blocks of size p, vn/q blocks of size q, vn/r blocks of size r and so on. But instead of doing the experiment in blocks with v plots in each, we are thus able to reduce the block size to the comparatively smaller sizes of $p, q, r, \ldots$ plots. The designs which Yates got by this artifice of confounding of main effects and interactions of certain fictitious factors, super-imposed on the varieties, were given by him the name quasi-factorial designs .

The simpler and more efficient cases of this design occur when $p = q = r = \ldots$ Then v becomes some power of the number p. If, in addition, p is a prime number or power of a prime number, it is possible to confound all main effects and all interactions of the pseudo-factors. This will ensure the losing of equal amount of information from all varietal comparisons and thus give symmetry to the design with respect to every variety. This special design was called the 'symmetrical' quasi-factorial design.

When v is not a factorizable number the idea of introducing pseudo-factors fails completely and to meet this case Yates [1936, 2] has developed the brilliant idea of balanced incomplete randomized blocks. In these designs it is possible to secure equal accuracy for comparisons between every pair of varieties, and the symmetrical quasi-factorial design of $v = (p)^m$ occurs as a special case.

In the Calcutta Statistical Laboratory, Bose and Nair [1939] have developed a general class of designs called partially balanced incomplete block designs of which Yates' quasi-factorial designs for $(p)^m$ varieties in blocks of $(p)^{m-1}$ plots, and his balanced incomplete designs, happen to be special cases. While developing the method of analysis for this general class of designs, it was found that the method given by Yates for analysing the data from quasi-factorial experiments with p^2 varieties in blocks of p plots may be replaced by a simpler method. One of the objects of this note is to illustrate this new procedure of analysis with the help of data from a quasi-factorial experiment on rice.

In the season of 1937-38 two quasi-factorial experiments with 49 and 100 varieties of paddy were laid out by Mr S. C. Chakravarty at the Chinsurah Farm, Bengal, in 28 randomized blocks of 7 plots and 40 randomized blocks of 10 plots respectively. The designs were prepared at the Statistical Laboratory. In the experiment with 100 varieties it is impossible to achieve symmetry between every pair of varieties as 10 is not a power of a prime number. In the other experiment symmetry could have been achieved if the shape of the experimental piece of land was such as to accommodate four 7×7 Latin Squares. As this was not possible the symmetry was sacrificed, and in both experiments

main effects only of the pseudo-factors were confounded. We shall use the second experiment for our illustration.

Besides the usual analyses of variance for grain and straw separately, the analysis of covariance also has been worked out. In an exploratory experiment with large number of varieties like the present one, it is not wise to limit the criterion of selection of strains to one character, namely, yield of grain alone. It is desirable to take into consideration the yield of both grain and straw (and also of other characters of economic importance as necessary); and for this purpose it is essential to include in the analysis the covariance between characters. Unfortunately adequate tests of significance and necessary tables for this purpose are not yet available. The problem is, however, receiving increasing attention [Lawley, 1938, 1939; Roy, 1939, 1, 2], and we may expect that necessary tables of significant levels will be available for this purpose in the near future. In the meantime we are taking this opportunity of explaining the procedure for calculating the various sums of products which will be needed in covariance analysis.

As a preliminary step, we have used the covariance analysis for a brief discussion of the method of selecting the varieties when the yields of grain and straw are both taken into consideration.

Details of lay-out

One hundred *aman* strains (other than *patnais*), a list of which is given in the appendix were selected for this experiment. These strains were assigned, at random, one hundred serial numbers 00, 01, 02,.....09, 10, 11, ...19, ... 90, 91,.....99, which are noted in column (1) of the appendix. These numbers were then written in the form of a 10×10 square lattice of the following pattern :—

00	10	20	30	40	50	60	70	80	90
01	11	21	31	41	51	61	71	81	91
02	12	22	32	42	52	62	72	82	92
03	13	23	33	43	53	63	73	83	93
04	14	24	34	44	54	64	74	84	94
05	15	25	35	45	55	65	75	85	95
06	16	26	36	46	56	66	76	86	96
07	17	27	37	47	57	67	77	8	97
08	18	28	38	48	58	68	78	88	98
09	19	29	39	49	59	69	79	89	99

The variety occurring in the i-th column and j-th row of this square is denoted as variety [ij] in which both i and j vary from 0 to 9.

The varieties bearing numbers occurring in the same row or in the same column constitute a set. It is clear that there are only 20 such sets, of which 10 sets correspond to the 10 columns and the other 10 sets correspond

to the 10 rows of the above square. The first 10 sets will be said to constitute group I, and the second 10 sets to constitute group II.

Each set must be replicated in the same number of randomized blocks according to the availability of the land. In this experiment only two replications were used, so that we had 40 randomized blocks giving four replications of each variety. The size of each plot was 8 ft. 3 in. × 8 ft. 3 in. Leaving a border of 9 in. all around, the net size came to 7 ft. 6 in. ×7 ft. 6 in.

The two replicated blocks of each of the 20 sets were first assigned at random among the total of 40 blocks. The 10 varieties of a set were allotted in a serial order in a random direction in one of the blocks assigned to that set, and in the other block they were randomized. The actual field layout is shown on the next page. The blocks have been numbered 1 to 40 ; and Table II gives, besides other things, the serial numbers of the blocks in which each set of the two groups was replicated.

Season and nature of crop

The season was quite favourable for rice ; and transplanting for this experiment was done on 28th July 1937. The rainfall was slightly above normal, and the distribution was quite regular ; and from the agricultural point of view the crop was considered to be normal. The normal rainfall and the rainfall during 1937-38 as recorded at the Chinsurah Farm are shown in Table I.

Table I

Rainfall at Chinsurah Farm during the season 1937-38

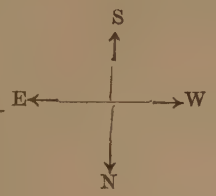
Month	Normal rainfall	Rainfall during the year 1937-38	Difference	Number of rainy days
April 1937	2·46	1·76	—0·70	2
May 1937	5·85	3·24	—2·61	10
June 1937	10·56	14·55	+3·99	14
July 1937	11·28	9·43	—1·85	25
August 1937	11·64	12·66	+1·02	21
September 1937	8·40	11·49	+3·09	21
October 1937	4·09	4·40	+0·31	6
November 1937	0·66	*Nil*	—0·66	*Nil*
December 1937	0·19	*Nil*	—0·19	*Nil*
January 1938	0·38	0·25	—0·13	1
February 1938	1·20	1·81	+0·61	3
March 1938	1·58	0·32	—1·26	1
Total	58·29	59·91	+1·62	104

Primary data

The primary data consist of yields of grain and straw expressed in ounces per plot. These are fully set out in Table II (*a*, *b*). The yield of straw was determined with less precision than the yield of grain. The total sum of

squares with 399 degrees of freedom, and the block sum of squares with 39 degrees of freedom were calculated directly from Table II (*a*, *b*) for yield of grain as well as yield of straw, and also the corresponding sum of products. It is not necessary to give details about the calculation of these quantities.

Lay-out plan of the experiment



	94	84	74	64	34	14	04	54	44	24	Block No. 40		
	65	20	98	05	91	70	20	53	78	30	63	76	40
	35	21	94	95	41	71	10	73	08	31	66	66	41
	85	22	90	75	21	72	30	93	68	32	60	56	42
	15	23	97	45	11	73	60	03	58	33	61	26	43
	55	24	92	15	31	74	80	83	18	34	68	16	44
	95	25	96	35	01	75	50	23	98	35	69	06	45
	45	26	99	55	71	76	00	13	28	36	64	96	46
	25	27	91	25	81	77	70	63	38	37	67	46	47
	75	28	93	85	51	78	40	43	88	38	62	86	48
	05	29	95	65	61	79	90	33	48	39	65	36	49

Block No.	27	28	29	30	31	32	33	34	35	36	37	38	39
	47	80	00	89	60	46	39	97	54	10	11	50	50
	42	81	07	99	10	26	34	67	84	11	18	57	51
	41	82	04	49	70	76	31	27	44	12	15	51	52
	43	83	01	79	20	66	37	77	64	13	17	55	53
	49	84	03	69	80	06	32	07	04	14	13	53	54
	48	85	08	09	30	16	35	17	14	15	14	54	55
	45	86	02	19	00	36	36	37	94	16	19	56	56
	44	87	06	29	50	56	30	87	74	17	12	58	57
	46	88	09	39	90	86	33	57	24	18	10	52	58
	40	89	05	59	40	96	38	47	34	19	16	59	59
Block No.	14	15	16	17	18	19	20	21	22	23	24	25	26
	71	57	60	03	00	79	02	29	90	86	01	38	82
	78	37	61	13	01	59	52	23	91	81	71	58	32
	73	87	62	83	02	39	92	22	92	80	41	88	02
	76	77	63	43	03	99	32	20	93	88	11	28	22
	79	67	64	53	04	49	72	28	94	83	31	78	92
	72	17	65	93	05	69	62	27	95	82	81	08	42
	70	97	66	33	06	89	82	21	96	89	21	98	52
	74	07	67	73	07	09	12	24	97	85	61	68	12
	77	47	68	63	08	29	22	26	98	87	91	18	62
	75	27	69	23	09	19	42	25	99	84	51	48	72
Block No.	1	2	3	4	5	6	7	8	9	10	11	12	13

TABLE

Yield of grain and of straw in each plot (upper figures

Group

Set 1	Bl. 5	Bl. 16	Set 2	Bl. 23	Bl. 24	Set 3	Bl. 8	Bl. 28	Set 4	Bl. 20	Bl. 36	Set 5	Bl. 14	Bl. 39
00	46·5	64·0	10	52·5	43·0	20	42·0	51·5	30	40·0	63·0	40	50·0	52·0
	40	58		68	52		48	84		46	80		56	80
01	49·0	54·5	11	34·0	42·0	21	40·0	45·5	31	56·5	59·0	41	56·0	41·5
	66	68		58	82		52	80		56	86		72	80
02	41·0	49·5	12	51·0	42·5	22	42·5	59·0	32	41·0	48·5	42	49·5	46·0
	48	60		66	56		56	84		64	82		78	68
03	42·5	38·5	13	51·5	50·0	23	40·0	55·0	33	38·5	57·5	43	56·5	47·5
	42	58		82	58		38	72		46	72		64	78
04	40·5	48·0	14	51·5	58·5	24	45·0	61·0	34	53·5	55·5	44	48·0	54·5
	56	80		60	62		58	94		62	66		64	70
05	44·0	43·5	15	48·5	48·0	25	49·0	59·5	35	41·5	57·5	45	58·0	67·5
	46	46		80	80		68	102		48	74		64	78
06	42·5	47·5	16	42·0	40·5	26	47·5	54·5	36	44·5	52·5	46	53·0	61·0
	40	52		70	60		64	74		48	60		66	76
07	43·0	51·5	17	40·0	49·5	27	43·5	61·0	37	47·5	60·0	47	55·0	56·5
	50	64		60	76		48	74		74	84		70	72
08	51·0	54·0	18	44·0	60·5	28	40·0	52·5	38	36·5	57·0	48	58·5	59·0
	52	60		68	98		54	72		38	64		64	68
09	48·0	44·0	19	36·0	45·0	29	44·0	60·0	39	51·0	51·0	49	53·5	56·5
	64	52		52	72		56	78		60	66		76	68

II (*a*)

indicate grain yield ; lower figures indicate straw yield)

I

Set 6	Bl. 25	Bl. 26	Set 7	Bl. 3	Bl. 37	Set 8	Bl. 1	Bl. 32	Set 9	Bl. 10	Bl. 15	Set 10	Bl. 9	Bl. 29
50	50·5	56·5	60	38·0	44·5	70	44·0	62·0	80	48·0	54·0	90	44·5	74·5
	58	68		56	74		68	110		52	54		54	106
51	48·0	56·5	61	41·0	60·0	71	55·0	61·0	81	46·0	53·5	91	44·5	53·0
	56	64		50	76		56	84		52	68		54	72
52	44·5	55·5	62	35·5	55·0	72	54·0	60·0	82	35·5	43·5	92	41·0	51·5
	48	56		40	78		72	92		38	50		48	82
53	49·0	51·5	63	46·5	61·0	73	51·5	57·0	83	42·0	52·5	93	39·0	55·5
	66	74		44	72		60	102		46	64		46	74
54	46·5	53·0	64	41·5	58·5	74	51·5	55·5	84	52·5	49·5	94	44·5	63·0
	70	80		60	82		64	72		74	78		48	106
55	50·0	53·5	65	45·5	54·0	75	54·5	55·5	85	40·0	42·0	95	35·5	44·0
	64	64		74	86		68	74		56	64		46	64
56	46·0	43·5	66	38·0	28·0	76	46·0	52·0	86	39·0	47·5	96	47·5	68·0
	64	54		56	84		68	80		54	58		52	86
57	56·0	51·0	67	48·5	57·0	77	48·5	50·5	87	45·0	41·0	97	47·0	76·0
	66	62		48	70		72	72		52	56		62	122
58	50·0	50·5	68	40·0	47·5	78	46·0	50·0	88	50·5	49·0	98	52·0	57·5
	58	60		68	80		82	82		50	54		66	84
59	36·5	42·5	69	43·5	45·0	79	48·5	51·0	89	43·5	40·0	99	54·0	58·0
	52	58		74	80		48	54		60	56		60	80

TABLE

Yield of grain and of straw in each plot (upper figures

Group

Set 1	Bl. 18	Bl. 33	Set 2	Bl. 11	Bl. 31	Set 3	Bl. 7	Bl. 13	Set 4	Bl. 4	Bl. 34	Set 5	Bl. 22	Bl. 40
00	52·5	61·0	01	48·0	63·0	02	37·5	50·0	03	41·0	57·0	04	46·0	57·5
	48	52		56	78		44	64		48	64		68	78
10	51·5	54·0	11	38·5	42·0	12	45·5	55·5	13	43·0	52·5	14	53·5	75·0
	68	76		46	72		62	74		50	62		60	90
20	51·5	50·0	21	38·0	48·0	22	49·5	50·0	23	45·0	48·0	24	41·5	64·0
	64	80		52	80		64	64		48	50		50	84
30	46·5	53·5	31	47·0	59·0	32	36·0	41·0	33	42·0	55·5	34	45·5	69·0
	56	82		40	72		48	72		50	64		50	96
40	44·0	55·5	41	43·5	60·0	42	43·5	40·5	43	37·0	50·0	44	47·5	57·0
	52	64		60	82		64	60		40	60		76	72
50	45·0	53·0	51	50·5	48·5	52	40·0	51·0	53	43·0	52·0	54	54·0	60·0
	62	66		54	60		40	56		76	112		96	84
60	49·0	49·5	61	47·0	56·0	62	35·5	58·5	63	46·0	56·5	64	53·5	64·0
	78	82		60	64		42	80		46	62		88	76
70	48·0	50·0	71	47·0	58·5	72	41·0	61·5	73	44·0	57·5	74	40·5	57·0
	66	72		48	62		58	82		56	84		52	80
80	55·5	56·0	81	42·0	52·5	82	37·0	38·5	83	40·0	54·0	84	52·0	62·0
	56	68		50	64		34	42		48	64		78	82
90	42·0	58·0	91	49·0	49·0	92	35·5	44·0	93	37·5	60·0	94	42·5	70·0
	48	64		56	82		38	58		48	94		58	116

II (*b*)

indicate grain yield ; lower figures indicate straw yield)

II

Set 6	Bl. 27	Bl. 30	Set 7	Bl. 19	Bl. 38	Set 8	Bl. 2	Bl. 21	Set 9	Bl. 12	Bl. 35	Set 10	Bl. 6	Bl. 17
05	60·0	66·5	06	46·5	56·0	07	45·0	47·5	08	51·5	62·0	09	41·0	47·0
	62	82		52	66		58	64		52	74		42	62
15	59·0	53·5	16	45·5	55·5	17	38·0	44·0	18	56·5	62·5	19	45·0	44·0
	98	80		64	82		62	74		102	102		56	68
25	60·0	54·0	26	51·0	57·5	27	57·0	58·0	28	45·0	49·0	29	52·0	49·5
	82	80		72	82		64	66		56	60		68	68
35	70·5	62·5	36	47·0	50·5	37	37·0	39·0	38	41·5	52·0	39	51·0	39·5
	100	82		52	62		62	60		48	62		60	48
45	64·5	65·0	46	58·5	63·5	47	45·0	41·0	48	51·5	54·5	49	42·0	50·5
	68	76		66	78		52	46		60	56		52	66
55	60·0	49·5	56	42·0	46·5	57	38·5	39·5	58	43·5	60·0	59	35·5	34·5
	98	66		60	76		50	58		58	110		50	48
65	65·5	52·5	66	41·5	32·0	67	45·5	55·0	68	45·5	49·5	69	32·5	39·0
	82	80		76	86		48	62		78	82		54	78
75	61·0	65·0	76	51·5	31·0	77	36·5	47·5	78	37·0	56·0	79	38·5	49·5
	70	82		82	82		50	64		72	92		34	50
85	53·5	48·5	86	42·5	54·0	87	39·0	38·5	88	53·5	64·5	89	38·5	51·5
	80	66		52	68		44	44		56	68		50	72
95	49·5	48·5	96	43·0	63·0	97	45·0	58·5	98	47·5	53·5	99	43·5	52·5
	74	90		48	76		60	72		64	68		52	64

Sum of squares and products due to varieties

It is in the calculation of the sum of squares and of products for variety, with 99 degrees of freedom, that all the complications of analysis set in. But once these sums are obtained, the residual sum of squares may be obtained by subtraction : Total *minus* Blocks *minus* Varieties.

The table of analysis of variance given by Yates [1936] mentions eleven sources of variation, of which five go to make up the variation among blocks, three go to make up the variation among varieties and three go to uncontrolled variation (namely, residual). Speaking generally, we need not take the trouble of calculating the sums of squares due to each of these eleven sources of variation. We are mostly interested to find out the value of the sums of squares for the three items : Blocks, Varieties and Residual ; and this is what we shall consider in the present paper.

The sums of squares and sum of products due to blocks are easily obtained from the totals of the 40 blocks. In getting the sums of squares and sum of products due to varieties, we are using a new procedure which simplifies considerably the computational work.

New procedure

We have 40 blocks with 10 plots each. We first calculate the mean yield of grain of each block. We next subtract from every plot yield the mean yield of the block in which the plot is located ; and call these the corrected values of the yield. There are four plots for each variety ; we next add the four corrected values of yield of each variety, and write this quantity as Q_{ij} for variety [ij]. It is obvious that the sum of the 100 values of Q_{ij} is zero. It is also clear that Q_{ij} can be calculated more easily by taking 10 times the total yield of variety [ij] and subtracting from it the sum of the total yields of the four blocks in which it has occurred, and then dividing the result by 10.

We then arrange Q_{ij} in a two-way table as shown in Table III ; and obtain the marginal means $\bar{Q}_i$ and $\bar{Q}_j$. If V_{ij} be the estimate of the effect of the variety [ij] on yield of grain, as measured from the general mean, we have

$$V_{ij} = \tfrac{1}{4}(Q_{ij} + \bar{Q}_i + \bar{Q}_j) \qquad (1)$$

which is obtained from Bose and Nair's general formula, after suitable substitution and simplification*.

It is easy to calculate V_{ij} from Table III. The mean of all V_{ij} will be zero. As it is usual to present varietal means instead of varietal effects, we may add to each V_{ij} the general mean for the whole experiment, and get the varietal means shown in Table IV. It should be noted that the varietal mean shown here is not the ' crude ' mean of the observed yields of the four plots under a given variety, but is the mean yield per plot of the given variety after adjusting for block effects. These adjusted varietal means are, therefore, comparable among themselves. In Table IV we thus obtain the summary of the results of the experiment before calculating the sum of squares. This is only logical, as estimation should precede tests of significance.

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* For Yates' quasifactorial designs of p^2 varieties in blocks of p plots forming l groups of p sets each, and with r replications of each variety,

$$V_{ijk\ldots} = \frac{1}{r(l-1)}\left\{(l-1)\,Q_{ijk\ldots} + \bar{Q}_{i\ldots} + \bar{Q}_{.j\ldots} + \bar{Q}_{..k\ldots} + \ldots\right\}$$

In our case, $l=2$, $=4$.

TABLE III

Values of Q_{ij} (yield of grain)

i / j	0	1	2	3	4	5	6	7	8	9	Total	Mean ($\bar{Q}_j$)
0	27·10	5·35	—6·90	—0·80	—9·10	3·35	—14·35	—4·00	19·45	11·35	31·45	3·145
1	21·50	—35·25	—26·50	21·60	—5·70	5·75	12·55	17·40	3·85	—8·25	6·95	0·695
2	—5·45	12·30	12·55	—23·85	—17·65	2·80	2·60	21·95	—26·10	—22·20	—43·05	—4·305
3	—11·45	7·80	—7·45	—3·85	—13·15	0·30	21·10	8·45	0·90	—9·20	—6·55	—0·655
4	—13·50	34·25	1·00	11·10	—12·20	3·25	13·55	—12·10	13·35	3·75	42·45	4·245
5	2·80	—0·95	6·30	13·90	30·10	—2·95	7·85	13·70	—24·35	—44·45	1·95	0·195
6	0·35	—7·40	13·35	—4·55	30·15	—18·90	—51·10	—22·75	—6·30	18·60	—48·55	—4·855
7	3·20	—11·05	30·70	—7·20	0·00	—3·55	23·75	—11·90	—17·45	31·95	38·45	3·845
8	20·55	26·80	—16·45	—17·85	11·85	1·30	—14·90	—20·05	22·40	1·80	15·45	1·545
9	—2·00	—10·75	18·50	3·60	6·80	—38·25	—20·45	—5·60	—5·65	15·25	—38·55	—3·855
Total .	43·10	21·10	25·10	—7·90	21·10	—46·90	—19·40	—14·90	—19·90	—1·40	0	0
Mean ($\bar{Q}_i$)	4·31	2·11	2·51	—0·79	2·11	—4·69	—1·94	—1·49	—1·99	—0·14	0	

TABLE IV

Estimated varietal effects on yield of grain (V_{ij} + g. m.)*

j \ i	0	1	2	3	4	5	6	7	8	9
0	58·2125	52·2250	49·2625	49·9625	48·6125	50·0250	46·2875	48·9875	54·7250	53·1625
1	56·2000	41·4625	43·7500	54·9500	48·8500	50·0125	52·4000	53·7250	50·2125	47·6500
2	48·2125	52·1000	52·2625	42·3375	44·6125	48·0250	48·6625	53·6125	41·4750	42·9125
3	47·6250	51·8875	48·1750	48·2500	46·6500	48·3125	54·2000	51·1500	49·1375	47·0750
4	48·3375	59·7250	51·5125	53·2125	48·1125	50·2750	53·5375	47·2375	53·4750	51·5375
5	51·4000	49·9125	51·8250	52·9000	57·6750	47·7125	51·1000	52·6750	43·0375	38·4750
6	49·5250	47·0375	52·3250	47·0250	56·4250	42·4625	35·1000	42·3000	46·2875	52·9750
7	52·4125	48·3000	58·8375	48·5375	51·0625	48·4750	55·9875	47·1875	45·6750	58·4875
8	56·1750	57·1875	46·4750	45·3000	53·4500	49·1125	45·7500	44·5750	55·0625	50·3750
9	49·1875	46·4500	53·8625	49·3125	50·8375	37·8750	43·0125	46·8375	46·7000	52·3875

*General mean (g. m.)=49·58.

TABLE V

Values of Q'ij (yield of straw)

j \ i	0	1	2	3	4	5	6	7	8	9	Total	Mean ($\bar{Q}'_j$)
0	—42·6	—2·4	10·0	6·0	—19·6	—0·6	24·4	37·6	—14·0	0·4	—0·8	—0·08
1	34·0	—1·8	4·6	2·6	29·0	—14·0	—9·0	—21·8	—3·4	—1·0	19·2	1·92
2	—8·8	7·4	17·8	23·8	14·2	—38·8	—9·8	41·4	—64·2	—29·8	—46·8	—4·68
3	—20·8	—6·6	—50·2	—18·2	—21·8	81·2	—33·8	31·4	—14·2	—1·8	—54·8	—5·48
4	18·4	—17·4	—3·0	—7·0	—12·6	52·4	17·4	—33·4	45·0	33·4	93·2	9·32
5	—34·0	42·2	36·6	16·6	—15·0	8·0	27·0	—13·8	—7·4	—27·0	33·2	3·32
6	—38·4	1·8	18·2	—43·8	6·6	—8·4	28·6	25·8	—19·8	—17·4	—46·8	—4·68
7	9·8	20·0	0·4	36·4	—17·2	—4·2	—23·2	—6·0	—33·6	58·8	41·2	4·12
8	—14·2	92·0	—35·6	—57·6	—35·2	19·8	30·8	38·0	—27·6	— 1·2	9·2	0·92
9	—4·4	—2·2	20·2	—7·8	6·6	—30·4	36·6	—76·2	10·2	0·6	—46·8	—4·68
Total .	—101·0	133·0	19·0	—49·0	—65·0	65·0	89·0	23·0	—129·0	15·0	0	0
Mean ($\bar{Q}'_i$) .	—10·10	13·30	1·90	—4·90	—6·50	6·50	8·90	2·30	—12·90	1·50	0	

TABLE VI

Estimated varietal effects on yield of straw (V'_{ij} + g. m.)*

j \ i	0	1	2	3	4	5	6	7	8	9
0	52·50	68·40	68·65	65·95	59·15	67·15	74·00	75·65	58·95	66·15
1	72·15	69·05	67·80	65·60	71·80	64·30	66·15	61·30	62·10	66·30
2	59·80	69·70	69·45	69·25	66·45	56·45	64·30	75·45	45·25	57·45
3	56·60	66·00	52·25	58·55	57·25	86·25	58·10	72·75	57·55	64·25
4	70·10	67·00	67·75	65·05	63·25	82·75	74·60	60·25	76·05	76·75
5	55·50	80·40	76·15	69·45	61·15	70·15	75·50	63·65	61·45	60·15
6	52·40	68·30	69·55	52·35	64·55	64·05	73·90	71·55	56·35	60·55
7	66·65	75·05	67·30	74·60	60·80	67·30	63·15	65·80	55·10	81·80
8	59·85	92·25	57·50	50·30	55·50	72·50	75·85	76·00	55·80	66·00
9	60·90	67·30	70·05	61·35	64·55	58·55	75·90	46·05	63·85	65·05

*General mean (g. m.)=65·695

Similar calculations can be made for the yield of straw. Let Q'_{ij} and V'_{ij} correspond, in the case of straw, to Q_{ij} and V_{ij} defined in the case of yield of grain. Tables V and VI give the values of Q'_{ij} and V'_{ij} respectively.

Having calculated the values of these four quantities (Q_{ij}, V_{ij} and Q'_{ij}, V'_{ij}) we get the sum of squares due to varieties in the case of yield of grain with the help of the formula

$$\sum_{i=0}^{9} \sum_{j=0}^{9} V_{ij} Q_{ij} \qquad (2)$$

and the sum of squares due to varieties in the case of yield of straw from the formula

$$\sum_{i=0}^{9} \sum_{j=0}^{9} V'_{ij} Q'_{ij} \qquad (3)$$

The sum of products due to varieties for yield of grain and yield of straw can be obtained by either of the two expressions :

$$\sum_{i=0}^{9} \sum_{j=0}^{9} V_{ij} Q'_{ij} \text{ or } \sum_{i=0}^{9} \sum_{j=0}^{9} V'_{ij} Q_{ij} \qquad (4)$$

which are identical. It is convenient, therefore, to calculate the product independently in both ways which furnishes a check on the whole set of calculations.

Tests of significance

Table VII gives the full analysis of variance and covariance.

Table VII

Analysis of variance and covariance

Variation due to	D. F.	Sum of product of grain and straw	Sum of squares		Coefficient of correlation
			Grain	Straw	
Blocks .	39	21917·10	12801·80	44680·79	+0·9164
Varieties .	99	1737·68	7694·07	23243·79	+0·1299
Error .	261	7230·22	5765·70	21074·21	+0·6559
Total .	399	30885·00	26261·57	88998·79	

Ratios of variances due to varieties and residual show that there are significant differences among the varieties with respect to yield of grain as well as of straw. These are shown in Table VIII.

TABLE VIII

Test of significance of varietal effects

Variation due to	D. F.	Variance		Ratio of variances		Expected R. V.	
		Grain	Straw	Grain	Straw	5 per cent	1 per cent
Blocks . .	39	328·26	1145·66				
Varieties .	99	77·71	234·79	3·52	2·91	<1·57	<1·88
Error . .	261	22·09	80·74				
Total .	399						

The standard error per plot for yield of grain is 4·70 or 9·48 per cent of mean. The standard error per plot for yield of straw is 8·98 or 13·67 per cent of mean. These compare well with the precision of ordinary randomized block experiments.

Tables IV and VI supply the summary of results from which detailed tests of significance can be used for differences between any pair of varieties. The varietal means were calculated correct to four decimal places for grain and two decimal places for straw in order to maintain a high order of precision in the sums of squares and of products.

The standard error of the differences between two varieties occurring in the same row or column is $\sqrt{(\frac{2}{4} \times \frac{1}{11})}$ times the standard error per plot, which works out to be 3·49 for grain and 6·66 for straw. The corresponding critical differences, at 5 per cent and 1 per cent levels, are respectively 6·87 and 9·05 for grain and 13·12 and 17·29 for straw.

The standard error of the difference between two varieties not occurring in the same row or column is $\sqrt{(\frac{2}{4} \times \frac{7}{10})}$ times the standard error per plot and works out to be 3·64 for grain and 6·95 for straw. The corresponding critical differences, at 5 per cent and 1 per cent levels, are respectively 7·16 and 9·44 for grain and 13·69 and 18·04 for straw.

There are 100 C_2 or 4950 comparisons between all pairs of varieties. Of these, 900 belong to pairs occurring in the same row or column ; and 4050 to pairs not having a row or column in common with them. Thus, for example, of the three varieties numbered 42, 45 and 82, the pair formed with 42 and 45 and the pair formed with 42 and 82 belong to the first kind of comparisons ; and the pair formed with 45 and 82 belongs to the second kind of comparisons. It will be noted that comparisons of the second kind have a larger error than the comparisons of the first kind. This is due to the fact that varietal pairs of the second kind do not occur together in the same block. Comparisons among them are thus affected by a greater amount of block variation than comparisons among pairs of the first kind which occur together in the same block.

Two more tables may be constructed rearranging the values of Tables IV and VI according to their decreasing magnitude, to show at a glance which varieties form classes of higher or lower yielders of grain and of straw,

This has been done in another way in Table IX, which shows against each variety its rank for yield of grain as well as for yield of straw.

TABLE IX

Ranked position of the varieties (upper figures indicate the rank for yield of grain ; lower figures indicate the rank for yield of straw)

i	0	1	2	3	4	5	6	7	8	9
	4	31	51	47	58	45	83	55	13	22
0	94	35	34	51	78	42	18	12	79	47
	8	97	89	12	56	46	27	16	44	70
1	22	33	37	53	23	58	48	69	66	46
	65	32	30	94	87	68	57	17	96	92
2	77	28	31	32	45	88	59	14	100	85
	71	33	66	64	79	62	14	38	53	74
3	87	49	97	81	86	2	82	20	83	60
	61	1	36	21	67	43	18	72	19	35
4	26	43	38	54	64	3	17	74	8	6
	37	48	34	24	5	69	39	25	90	98
5	91	5	7	30	70	25	13	63	67	75
	49	75	29	76	7	93	100	95	82	23
6	95	36	29	96	56	61	19	24	89	73
	26	63	2	59	40	60	10	73	85	3
7	44	15	40	16	72	39	65	52	93	4
	9	6	80	86	20	54	84	88	11	42
8	76	1	84	98	92	21	11	9	90	50
	52	81	15	50	41	99	91	77	78	28
9	71	41	27	68	57	80	10	99	62	55

CORRELATION BETWEEN GRAIN AND PADDY

The last column of Table VII gives the coefficient of correlation between yield of grain and yield of straw for variations due to blocks, varieties and residual (error).

The high correlation of $+0{\cdot}9164$ due to blocks indicates that blocks with large yields of grain also have large yields of straw, and blocks with low yields of grain have low yields of straw. This shows that the influence of soil fertility on the yield of both grain and straw is working in the same direction. That is, the yield of both grain and straw is greater in better type of soil which is just what is to be expected.

The inter-varietal correlation or the correlation between the mean yields of grain and of straw for the varieties is only +0·1299 which is insignificant at the 5 per cent level. It will be seen from the accompanying scatter diagram (Fig. 1) that there is little or no tendency towards clustering in the points. This shows that a variety having a high yield of grain does not necessarily have a high yield of straw. In fact, on an average among

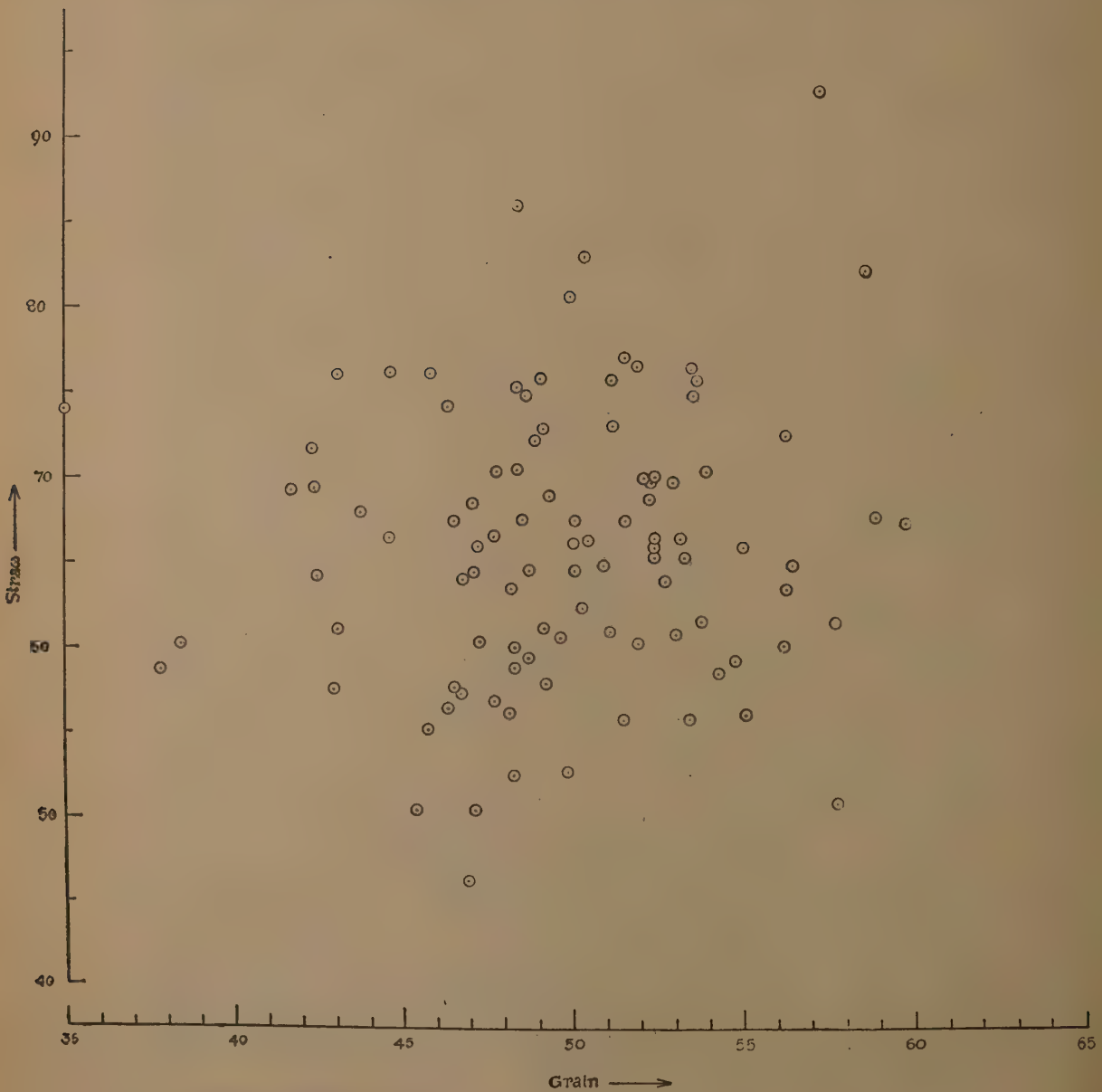

FIG. 1. Scatter diagram of the mean yields of grain and straw of the one hundred varieties

varieties giving high yields of grain there will be all kinds of yields of straw, high, medium and low. This clearly brings out the danger of confining our attention to a single character, say, the yield of grain, in pre-selection field trials.

The residual (error) correlation is +0·6559 which is significant at the one per cent level. This gives the correlation between yield of grain and of straw of individual plots after correcting for effects of both blocks and varieties. The significant correlation shows that the uncontrolled factors, such as differences in fertility from plot to plot, exert their influence in the same direction on both grain and straw.

Joint comparison of yields

Before concluding we shall make a few preliminary observations regarding a comparison of the varieties jointly on the basis of yields of both grain and straw.

If we attach the same importance to both grain and straw (which, of course, is not really justified from the agricultural or economic point of view), a rough way of assessing the relative value of the crop as from both the two characters, will be to add the two ranks, and arrange the varieties in accordance with their combined ranks. If there had been perfect correlation between the two characters, the combined ranks would have taken the values 2, 4, 6 .....200. In our case the combined rank shown in Table X starts from 7 and ends with 196, with repetitions at some of the values. Thus rank 7 is shared by the varieties 18 and 97. Variety 18 stood first also in the ranking for straw yield; but variety 14, which stood first in the ranking for grain yield, stands low in the combined ranking, due to its poor straw yield.

Table X

Sum of the ranks of grain and straw yields

i / j	0	1	2	3	4	5	6	7	8	
0	98	66	85	98	136	87	101	67	92	69
1	30	130	126	65	79	104	75	85	110	116
2	142	60	61	126	132	156	116	31	196	177
3	158	82	163	145	165	64	96	58	136	134
4	87	44	74	75	131	46	35	146	27	41
5	128	53	41	54	75	94	52	88	157	173
6	144	111	58	172	63	154	119	119	171	96
7	70	78	42	75	112	99	75	125	178	7
8	85	7	164	184	112	75	95	97	101	92
9	123	122	42	118	98	179	101	176	140	83

TABLE XI

Relative total money value of grain and straw (figures in parenthesis give the rankings)

i / j	0	1	2	3	4	5	6	7	8	9
0	69·70 (11)	67·19 (30)	64·28 (52)	64·39 (50)	61·55 (69)	64·71 (48)	62·48 (62)	65·54 (42)	67·62 (22)	67·63 (21)
1	71·98 (5)	56·57 (92)	58·58 (86)	69·30 (12)	64·56 (49)	64·08 (53)	66·87 (35)	67·13 (32)	63·80 (54)	62·15 (64)
2	61·29 (70)	67·35 (28)	67·45 (26)	57·49 (90)	69·15 (15)	60·37 (79)	62·73 (60)	70·12 (7)	51·37 (98)	55·48 (96)
3	60·01 (80)	66·33 (39)	59·60 (82)	61·06 (74)	59·17 (83)	67·18 (31)	66·91 (34)	67·06 (33)	61·73 (67)	61·13 (73)
4	63·67 (55)	74·37 (3)	66·33 (38)	67·44 (27)	61·95 (66)	68·38 (18)	69·86 (9)	60·42 (78)	70·11 (8)	68·33 (19)
5	63·64 (56)	67·50 (25)	68·48 (17)	68·09 (20)	61·05 (75)	63·06 (58)	67·62 (23)	66·60 (37)	56·48 (93)	51·63 (97)
6	60·99 (76)	61·98 (65)	67·54 (24)	58·48 (87)	70·57 (6)	56·47 (94)	51·27 (99)	57·95 (88)	58·61 (85)	66·22 (40)
7	68·99 (16)	64·72 (47)	73·56 (4)	64·86 (45)	64·36 (51)	63·20 (57)	69·80 (10)	61·58 (68)	57·73 (89)	76·38 (2)
8	69·27 (13)	77·37 (1)	59·05 (84)	56·30 (95)	65·59 (41)	64·97 (43)	62·34 (63)	61·20 (71)	67·27 (29)	64·81 (46)
9	62·51 (61)	61·17 (72)	69·19 (14)	62·73 (59)	64·96 (44)	50·68 (100)	59·62 (81)	56·91 (91)	60·67 (77)	66·62 (36)

From the economic point of view the procedure of using the joint rank for grain and straw yields is unsatisfactory, for the money returns from equal weights of grain and straw are quite different. A better plan is to use the total money return of the crop for both paddy and straw taken together. For example, for the crop under consideration, we find that Rs. 2 and As. 7 may be taken as the average price of one maund of grain and of one maund of straw respectively ; and we can reduce the yield of straw to equivalent quantities of grain by using the multiplier 7/32.

The mean yield of straw measured on this new scale is added to the mean yield of grain of each variety to assess the total money value of the yields of grain and straw. These are given in Table XI in which the ranks are written in parenthesis. Varieties 18 and 97 now stand differentiated, as first and second, though there was a tie between them for the first place in the ranking given in Table X. Variety 14, which stood low in Table X in spite of having the highest yield in grain, stands third in importance according to the assessment made in Table XI.

While judging the superiority of one variety to another, ranks are, however, not quite satisfactory, and rigorous tests of significance should be used. We can do this for the values given in Table XI by using an analysis of variance of the ' money value ', namely, of the variable.

$$M = X + \tfrac{7}{32} Y \qquad (5)$$

where X = yield of grain and Y = yield of straw. The relevant data are given in Table XII. The sum of squares in any line of this table is obtained by multiplying by $(7/32)^2$, (7/16) and (1) respectively the sum of squares of straw, sum of products, and sum of squares of grain, of the corresponding line of Table VII.

TABLE XII

Analysis of variance of total money value of grain and straw

——	D. F.	Sum of squares	Variance	Ratio of variances	
				Observed	Expected 1 per cent
Blocks	39	24528·5769	628·94		
Varieties . . .	99	9566·5567	96·63	2·54	<1·88
Error	261	9937·3552	38·07		
Total .	399	44032·4888			

The ratio of variances for M is highly significant, showing the high variation in the money value of the different varieties. The standard error per plot of the money value is 6·1705. The standard error of the difference between any two values occurring in the same row or column of Table XI is 4·576 and the critical differences at 5 per cent and 1 per cent levels are respectively 9·01 and

11·90. The standard error of the difference between any two values of Table XI not occurring in the same row or column is 4·780 and the critical differences at the 5 per cent and 1 per cent levels are respectively, 9·42 and 12·43. With the help of these critical values it is now possible to use tests of significance for comparing the money values of any two varieties.

Summary

A new method of analyses of variance and covariance has been discussed, with the help of actual experimental data of a quasi-factorial experiment on paddy with one hundred varieties arranged in a square lattice design ; and it has been shown that the new procedure will considerably reduce the computational labour.

From the analysis of covariance it has been found that there is little or no inter-varietal correlation between mean yield of grain and mean yield of straw of the different varieties. This shows the need of taking into consideration more than one economic character of the plant, in this case, for example, the yield of both grain and straw in pre-selection trials.

For the purpose of grading the varieties it is clearly desirable to use a scale which will take into consideration both grain and straw. Two methods, namely, (1) the sum of the separate ranks of the two characters, and (2) the money return from both grain and straw have been briefly discussed for purposes of illustration. The varieties were found to be significantly differentiated with regard to the money return.

Acknowledgements

Our sincere thanks are due to Mr S. C. Chakravarty, Rice Research Officer-Chinsurah Farm, Bengal, who was in charge of the field experiment, for supplying us with the primary material.

Our thanks are due to Mr Topobikash Basu, M.Sc., for assistance in computations ; and to the Imperial Council of Agricultural Research for financing a portion of the expenses.

Note added 11 December 1939

We are grateful to Rao Bahadur M. Vaidyanathan for having drawn our attention to a short paragraph on page 125 of the revised edition (1937) of C. H. Goulden's *Methods of Statistical Analysis* in which the author gives an expression for the sum of squares of varieties alternative to the one given by Yates. The expression used by us is entirely different and applicable to the wider class of ' Partially Balance Incomplete Block Designs ', dealt with in this paper.

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Appendix

Random No.	Name of strain		Random No.	Name of strain	
00	Kalma	107/36	50	Harimai	1180/34
01	Maula	1332/36	51	Bankumari	1031/36
02	Jatakalma	389/33	52	Uttarekalma	386/33
03	Baktulsi	928/36	53	Karticsail	1350/36
04	Rupsail	849/36	54	Rangi	475/32
05	Ahamsail	1129/36	55	Kalakartic	135/32
06	Madhumalati	1515/36	56	Tengra	1541/36
07	Kanakchur	1221/36	57	Nona	251/32
08	Dudkalma	144/36	58	Jhingasail	220/36
09	Ramsail	1283/36	59	Kamalbhog	1127/36
10	Ailsail	1092/36	60	Kamalbhog	1532/36
11	Gopalbhog	916/36	61	Sundarsail	1346/36
12	Latamagurasail	1357/36	62	Peswari	1083/36
13	Baskamalbhog	1342/36	63	Jhingasail	221/36
14	Dudkalma	191/36	64	Kalma	94/36
15	Kartikbalam	1597/36	65	Luchai 15	945/36
16	Mugaibalam	1547/36	66	Tengrasylhet	940/36
17	Agniswar	1712/36	67	Dudkalma	366/33
18	Lalkalma	158/36	68	Kamanisail	938/36
19	Bankumari	1355/36	69	Kamalbhog	1607/36
20	Sarunagra	284	70	Karticbalam	1594/36
21	Kalma	112/36	71	Dudkalma	85/36
22	Peswari	1139/36	72	Jhingasail	275/36
23	Kalamkati	47/35	73	Seetasail	833/36
24	Mota	1690/36	74	Brindabansail	1219/36
25	Jhingasail	215/36	75	Tengrasylhet	1324/36
26	Gangajal	1709/36	76	Mahipal	1194/34
27	Harimai	1207/36	77	C-O 1	(1171/36)
28	Seetasail	496/32	78	Mausal 239	..
29	Lalkalma	176/32	79	Nagra 40	322/33
30	Chamarmani	874/36	80	Bachaibalam	1173/36
31	Kalma	95/36	81	Chamarmani	876/36
32	Harimai	1211/36	82	Baktulsi	915/36
33	Localnagra	..	83	Algorasail	1118/36
34	Kalma	182/36	84	Rupsail	196/33
35	T 31 (Pusa)	..	85	Ramsail	1503/36
36	Bakchur	..	86	Sitasail	830/36
37	C-O 1	..	87	Baktulsi	914/36
38	Nagra 100	266/32	88	Dudkalma	133/36
39	Jatakalma	401/33	89	GEB 24	..
40	SC 54/10	(1326/36)	90	Bhasamanik	..
41	Peswari	1096/36	91	Metekalma	183/32
42	Kamalbhog	1523/36	92	Dudkalma	166/36
43	Rudin	1531/36	93	Baktulshi	960/36
44	T 24 (Pusa)	..	94	Magurasail	1519/36
45	Nagra	126 (308/33)	95	T 52 Pusa	..
46	Patharkuchi	1273/36	96	Seetasail	834/36
47	Baskamalbhog	1036/36	97	Auspapri	1172/36
48	Nagra	65/5 (262/32)	98	Pubebalam	1599/36
49	Sitasail	815/36	99	Harimai local	1110/36

THE ANALYSIS OF SIMPLE NON-SYMMETRICAL EXPERIMENTS *

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(Received for publication on 19 September 1939)

Introduction

THE analyses of symmetrical experimental designs, viz. Latin squares, randomized blocks, incomplete symmetrical randomized blocks, etc., are simple and fairly well-known. When these layouts happen to become asymmetrical due to some cause which is beyond the control of the experimentern the analysis becomes complicated and can be done only by the actual application of the principle of least squares to the data. Methods for the analyses of experiments involving a number of missing plots have already been given by Yates. The method given so far stops with the analysis of variance table which simply shows whether there is any difference between the various varieties (or treatments) on the whole. To obtain further information regarding the different varieties (or treatments), it is necessary to calculate the standard error of the various mean differences, which is very laborious when there are a large number of varieties with different replications. The present paper indicates how it is possible to obtain more information by dividing the varieties into different groups by the application of the principle of least squares a second time in such a way as to enable us to split the total sum of squares for varieties into sum of squares between groups and within groups of the varieties.

It must be clearly understood that by giving this method of analysis for asymmetrical experiments, it is not at all meant that experimenters can have their experiments in any way they choose. Symmetrical experiments are more efficient than non-symmetrical ones. But whenever experiments become asymmetrical due to unforeseen circumstances, the method outlined below can more advantageously be used for obtaining information on the different varieties.

Material

The material used for illustrating the method of analysis consists of a varietal yield trial with nine varieties conducted for the Imperial Economic Botanist at the Government Agricultural Farm, Bahraich (U. P.). The details of the experiment are given below :

Varieties tested . .	P. 4, P. 12, P. 52, P. 80-5, P. 111, P. 120, P. 165, C. 13, Pb. 518.
	(P stands for Pusa, Pb. for Punjab and C for Cawnpore)
Layout . . .	9 × 6 randomized blocks
Ultimate plot size . .	46 ft. × 12 ft. or 1/80 acre (approximately)

* Read before the Indian Science Congress held in Madras, 1940

General manuring	Sannhemp green manure
Sowing date	26 October 1937
System of sowing	Behind *desi* plough in furrows 8 in. to 9 in. apart
Irrigation given	One, 12 to 13 November 1937
Harvesting date	22 to 28 March 1938

Plan of the experiment showing the yield of grain per plot in pounds

I	...	...	G 15·50	F 12·25	D 24·75	B 24·75	E 15·75	H 31·25	A 19·00
II	...	...	...	C 27·00	H 33·00	A 16·25	G 17·50	F 19·25	E 23·75
III	...	...	...	D 24·50	G 18·75	H 27·00	E 20·75	C 27·75	B 28·75
IV	...	...	...	A 24·50	H 31·00	F 16·00	I 34·25	B 30·00	D 18·25
V	...	...	...	H 32·00	...	G 18·25	E 21·25	D 21·50	F 17·50
VI	...	...	F 15·00	G 16·00	C 21·25	I 23·75	D 17·00	E 18·75	B 23·75

The yields from plots left blank were very poor and hence have been omitted from the statistical analysis. A, B, C, D, E, F, G, H and I denote P. 4, P. 12, P. 52, P. 80-5, P. 111, P. 120, P. 165, C. 13 and Pb. 518 respectively.

Method of analysis

Constants a, b, c, d, e, f, g, h and i ; b_1, b_2, b_3, b_4, b_5 and b_6 representing the varietal and the block effects respectively are fitted to the data by applying the principle of least squares. It can easily be shown that the equations for determining the above constants are

Set 1

$$\begin{cases} 7m+7b_1+a+b+d+e+f+g+h = 143\cdot25 \text{ (Total for block I)} \\ 6m+6b_2+a+c+e+f+g+h = 136\cdot75 \text{ (} \quad \text{ II)} \\ 6m+6b_3+b+c+d+e+g+h = 147\cdot50 \text{ (} \quad \text{ III)} \\ 6m+6b_4+a+b+d+f+h+i = 154\cdot00 \text{ (} \quad \text{ IV)} \\ 5m+5b_5+d+e+f+g+h = 110\cdot50 \text{ (} \quad \text{ V)} \\ 7m+7b_6+b+c+d+e+f+g+i = 135\cdot50 \text{ (} \quad \text{ VI)} \end{cases}$$

Set 2

$$\begin{cases} 3m+3a+b_1+b_2+b_4 = 59\cdot75 \text{ (Total for variety A)} \\ 4m+4b+b_1+b_3+b_4+b_6 = 107\cdot25 \text{ (} \quad \text{ B)} \\ 3m+3c+b_2+b_3+b_6 = 76\cdot00 \text{ (} \quad \text{ C)} \\ 5m+5d+b_1+b_2+b_4+b_5+b_6 = 106\cdot00 \text{ (} \quad \text{ D)} \\ 5m+5e+b_1+b_2+b_3+b_5+b_6 = 100\cdot25 \text{ (} \quad \text{ E)} \\ 5m+5f+b_1+b_2+b_4+b_5+b_6 = 80\cdot00 \text{ (} \quad \text{ F)} \\ 5m+5g+b_1+b_2+b_3+b_5+b_6 = 86\cdot00 \text{ (} \quad \text{ G)} \\ 5m+5h+b_1+b_2+b_3+b_4+b_5 = 154\cdot25 \text{ (} \quad \text{ H)} \\ 2m+2i+b_4+b_6 = 58\cdot00 \text{ (} \quad \text{ I)} \end{cases}$$

For practical purposes the formation of the above equations is easy. The left hand side of set 1 is the sum of least square estimates of the different varieties in blocks I, II, ...VI *plus* the respective block

effects ; that of set 2 is the sum of least square estimates of the varieties multiplied by the number of times it occurs *plus* the effects of the blocks in which each variety falls, m is the general mean of all the plots and $b_1, b_2, \ldots\ldots b_6$ have been so selected that

$$7b_1+6b_2+6b_3+6b_4+5b_5+7b_6=0$$

By virtue of the above relation we will also find that

$$3a+4b+3c+5d+5e+5f+5g+5h+2i=0$$

Eliminating m, a, b, c, d, e, f, g, h and i from set 2 by the aid of set 1 we get

Set 3 .

$$\left\{\begin{array}{rrrrrrr}
325b_1- & 68b_2- & 63b_3- & 71b_4- & 60b_5- & 63b_6= & -526\cdot75\\
-68b_1+ & 272b_2- & 56b_3- & 44b_4- & 48b_5- & 56b_6= & 444\cdot00\\
-63b_1- & 56b_2+ & 277b_3- & 39b_4- & 48b_5- & 71b_6= & 363\cdot25\\
-71b_1- & 44b_2- & 39b_3+ & 259b_4- & 36b_5- & 69b_6= & 613\cdot25\\
-5b_1- & 4b_2- & 4b_3- & 3b_4+ & 20b_5- & 4b_6= & 26\cdot00\\
7b_1+ & 6b_2+ & 6b_3+ & 6b_4+ & 5b_5+ & 7b_6= & 0
\end{array}\right.$$

Solving the above set of equations we get

$b_1=-1\cdot16623$, $b_2=1\cdot37377$, $b_3=0\cdot96102$
$b_4=1\cdot74759$, $b_4=1\cdot11208$, $b_6=3\cdot12729$

Substituting these values in the 1st set of equations, we find

$a=-3\cdot09990$, $b=4\cdot84387$, $c=3\cdot23264$
$d=-1\cdot07029$, $e=-2\cdot14553$, $f=-6\cdot35285$
$g=-4\cdot99553$, $h=7\cdot67949$, $i=7\cdot32499$

The reduction in the sum of squares due to constants fitted is

$$b_1B_1+b_2B_2+b_3B_3+b_4B_4+b_5B_5+b_6B_6+aT_a+bT_b+cTc+dTd+eT_e+fT_f+gT_g+hT_h++iT_i,$$

Where $B_1, B_2, \ldots\ldots B_6$; $T_a, T_b, \ldots\ldots T_i$ are the blocks and the treatment totals respectively, and is equal to 1053·811.

Sum of squares for varieties alone is = 1053·811—sum of squares for blocks calculated in the usual way, i.e. = 1053·811—184·994 = 868·817.

We can now draw up the analysis of variance table after calculating the total sum of squares in the usual way.

Analysis of variance

Variance due to	Degrees of freedom	Sum of squares	Mean square
Blocks	5	184·994	..
Varieties	8	868·817	108·602
Error	23	173·014	7·522
Total	36	1226·825	

Before we proceed further, let us get the least square estimates of the various varieties. They are

a+m, b+m, ...i+m.

A=19·26496	B=27·20873	C=25·59750
D=21·29457	E=20·21933	F=16·01201
G=17·36933	H=30·04435	I=29·68985

From the analysis of variance table, we note that the differences among the various varieties are on the whole significant. Further information regarding the varieties can be had either by examining the mean differences with the help of their standard errors or by grouping the varieties into different classes which are possibly significantly different from one another. In non-symmetrical experiments it will be found that the latter method is more convenient and involves less labour. In our example, examining the least square estimates,* it looks that the nine varieties can be classified into four groups as follows :—

A=D=E. I; B=C. II; F=G. III; H=I. IV

Our object now is to see whether there is any significant difference between and within these groups. For this, fit constants x, w, y and z to represent these groups to the original data, i.e. m+x, m+w, m+y and m+z are the least square estimates of groups I, II, III and IV respectively on the assumption that there is no difference between the various varieties comprising the groups. The equations for determining the constants x, w, y and z ; b_1, b_2, b_3, b_4, b_5 and b_6 are

$$\left.\begin{aligned} 7m+7b_1+3x+w+2y+z &= 143\cdot25\\ 6m+6b_2+2x+w+2y+z &= 136\cdot75\\ 6m+6b_3+2x+2w+y+z &= 147\cdot50\\ 6m+6b_4+2x+w+y+2z &= 154\cdot00\\ 5m+5b_5+2x+2y+z &= 110\cdot50\\ 7m+7b_6+2x+2w+2y+z &= 135\cdot50 \end{aligned}\right\} \quad (1);$$

$$\left.\begin{aligned} 13m+13x+3b_1+2b_2+2b_3+2b_4+2b_5+2b_6 &= 266\cdot00\\ 7m+7w+b_1+b_2+2b_3+b_4+2b_6 &= 183\cdot25\\ 10m+10y+2b_1+2b_2+b_3+b_4+2b_5+2b_6 &= 166\cdot00\\ 7m+7z+b_1+b_2+b_3+2b_4+b_5+b_6 &= 212\cdot25 \end{aligned}\right\} (2)$$

As before, m is the general mean of all the plots, and $b_1, b_2, \ldots\ldots\ldots\ldots b_6$ are so selected that

$$7b_1+6b_2+6b_3+6b_4+5b_5+7b_6=0.$$

It may be noted that for practical purposes (1) is obtained from set 1 by putting a=d=e=x ; b=c=w ; f=g=y ; h=i=z and (2) from set 2 by adding up the equations involving a, d, e ; b, c ; f, g ; h, i ; and putting in the final equations a=d=e=x, b=c=w, f=g=y, h=i=z.

Eliminating $b_1, b_2, \ldots\ldots\ldots\ldots b_6$ we get

$$\begin{aligned} 13x+ \quad 7w+10y+ \quad 7z &= 827\cdot50\\ 1331x- \quad 24y- \quad 12z &= 26401\cdot50\\ -35x+1355w- \quad 5y- \quad 20z &= 34516\cdot25\\ -59x- \quad 20w-29y+1403z &= 39802\cdot75 \end{aligned}$$

Solving the above equations

$$x=-1\cdot95783,\ w=4\cdot13921,\ y=-5\cdot66257,\ z=7\cdot58611$$

Substituting the values in (1)

$$\begin{aligned} b_1&=-1\cdot11868 & b_2&=1\cdot01272 & b_3&=1\cdot17075\\ b_4&=1\cdot67960 & b_5&=1\cdot26607 & b_6&=-3\cdot09683 \end{aligned}$$

Reduction in the sum of squares due to the four groups and the blocks is 1037·756 and is given by $xT_x+wT_w+yT_y+zT_z+b_1B_1+\ldots\ldots\ldots b_6B_6$ where T_x, T_w, T_y and T_z are the four totals for the respective groups. Sum of squares due to blocks alone already calculated is 184·994. Hence the sum of squares between groups = 1037·756—184·994 = 852·762. Sum of squares within groups = 868·817—852·762 = 16·055. Now we can draw up the final

*This can be *roughly* done by the aid of S. E. for M_d calculated in the usual way on the available number of replications.

analysis of variance table which gives almost all the information regarding the various varieties.

Analysis of variance

Variance due to		Degrees of freedom	Sum of squares	Mean squares
Blocks		5	184·994	
Varieties	Between groups	3	852·762	284·254
	Within groups	5	16·055	3·211
Residual error		23	173·014	7·522
	Total	36	1226·825	

The above analysis of variance table shows that the differences between the four groups are highly significant. But the variance within groups is not significant. Thus it will be seen that the nine varieties can be divided into four groups which are significantly different.

SUMMARY

It has been shown that in the case of non-symmetrical experiments by applying the principle of least squares twice, it is possible to extract most of the information regarding the different varieties (or treatments) of the experiment. The first application gives the total sum of squares due to varieties. The subsequent application is so done as to classify the different varieties into groups which are significantly different from one another.

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A SUPPLEMENTARY NOTE ON THE ANALYSIS OF 3^3 AND 3^4 DESIGNS (WITH THREE-FACTOR INTERACTIONS CONFOUNDED) IN FIELD EXPERIMENTS IN AGRICULTURE

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(Received for publication on 10 July 1940)

IN the paper on the analysis of 3^3 and 3^4 designs published in a recent issue of this Journal (Vol. X, part II, April 1940, pp. 213-36) the method of calculation of the partially confounded three-factor interactions requires a small correction. In Table VI-*a* it was assumed that in order to get the corrected totals W', X', etc., it was sufficient to subtract J_1, J_2 and J_3 (Table V-*a*) from W_1, W_2 and W_3 respectively and so on. But, on examination, the degrees of freedom confounded are found to be as follows :—

(1), (2).....(9) refer to block Nos. (Table I-*a*).

I's, *J*'s, *R*'s and *C*'s refer to the respective diagonal, row and column totals in Table V-*a*.

ABC

Replication I	Replication II	
W_1	X_1	(1)+(6)+(8) (J_1)
W_2	X_2	(3)+(5)+(7) (J_2)
W_3	X_3	(2)+(4)+(9) (J_3)

ABD

Replication I	Replication II	
Y_1	Z_1	(1)+(5)+(9) (I_1)
Y_2	Z_2	(3)+(4)+(8) (I_3)
Y_3	Z_3	(2)+(6)+(7) (I_2)

ACD

Replication I	Replication II	
Z_1	W_1	(1)+(4)+(7) (R_1)
Z_2	W_2	(3)+(6)+(9) (R_3)
Z_3	W_3	(2)+(5)+(8) (R_2)

BCD

Replication I	Replication II	
X_1	Y_1	(1)+(2)+(3) (C_1)
X_2	Y_2	(4)+(5)+(6) (C_2)
X_3	Y_3	(7)+(8)+(9) (C_3)

Therefore in Table VI-*a*, for *ABC*, we have to subtract J_3s from W_2 and X_2 and J_2s from W_3 and X_3 ; for *ABD*, I_3s from Y_2 and Z_2 and I_2s from Y_3 and Z_3, and for *ACD*, R_3s from Z_2 and W_2 and R_2s from Z_3 and W_3.

There is no interchange in the case of *BCD*. Thus for *ABC* (W') the working sheet will appear as follows :—

ABC

	1	2	3	
W	2012	2011	2228	
	1363	1259	1316	(J_1, J_2 and J_3 of Table V-*a*)
W'	649	752	912	
instead of	649	695	969	and so on.

The totals thus obtained have been checked by calculating them independently from the replication in which the particular interaction is not confounded.

On the basis of these new totals the sum of squares in the final table of analysis of variance (Table X-*a*) corresponding to :—

ABC (W')	will be	1300·96	instead of	2217·18
ABC (X')	,,	4819·58	,,	12327·11
ABD (Y')	,,	2462·29	,,	4593·85
ABD (Z')	,,	2046·69	,,	5909·73
ACD (W')	,,	185·21	,,	30680·40
ACD (Z')	,,	4048·23	,,	954·74
and remainder		78237·91	,,	36417·86

The main point to be emphasized is that while applying the general rule regarding the block totals for estimating the unconfounded parts, it is important to see actually in any particular design which totals correspond to W_1, W_2, W_3 and so on and not subtract J_1, J_2, J_3 of the block totals for instance from the respective W_1, W_2 and W_3. In other words, for each design of the type considered, it is essential to see which block totals give the comparisons of the confounded degrees of freedom in each replication. This can easily be done with the help of Table 43 in Yate's [1937] bulletin on the 'Design and analysis of factorial experiments'.

I am thankful to Mr P. H. Carpenter of the Tocklai Tea Experimental Station (Assam) for bringing this point to my notice.

REFERENCE

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NOTE

NOTIFICATION NO. F. 1-9 (3)/40-A, DATED THE 29TH MAY 1940, ISSUED BY THE GOVERNMENT OF INDIA IN THE DEPARTMENT OF EDUCATION, HEALTH AND LANDS

THE following Order issued by the Ministry of Agriculture and Fisheries, London, called ' The Importation of Plants (Amendment) Order of 1940 ', is published for general information :—

STATUTORY RULES AND ORDERS 1940 No. 544

DESTRUCTIVE INSECT AND PEST, ENGLAND

THE IMPORTATION OF PLANTS (AMENDMENT) ORDER OF 1940 DATED APRIL 10, 1940

(D. I. P. 607)

The Minister of Agriculture and Fisheries, by virtue and in exercise of the powers vested in him under the Destructive Insects and Pests Acts, 1877 to 1927 (a), and of every other power enabling him in this behalf, orders as follows :—

Modification of the Importation of Plants Order of 1939

1. The Importation of Plants Order of 1939 (*b*) (hereinafter referred to as ' the principal Order ') is hereby modified in the manner provided by this Order.

Application to Spain of Articles 5, 6 and 7 of the principal Order and of the Third Schedule thereto

2. Article 5 (5), Article 6 (1) and (3), Article 7 (1) and (3) of the principal Order and Form A in the Third Schedule thereto shall be read and have effect as if in addition to the countries specifically mentioned Spain were mentioned therein ; and in respect of any plants potatoes raw vegetables and cider apples grown in Spain any certificate required by any of the said Articles shall be a certificate of a duly authorised Official of the Spanish Phytopathological Service.

Amendment of Article 6 of the principal Order

3. For Article 6 (2) of the principal Order shall be substituted :—

' (2) The landing in Englad nor Wales between the twenty-first day of April and the thirtieth day of September in any year of any raw vegetables grown in Belgium, Germany, Luxemburg, or the Netherlands is hereby prohibited unless in the case of a consignment landed between the twenty-first day of April and the thirty-first day of May in any year each consignment is accompanied by a certificate of origin vise by a competent authority in the country of origin stating the country and place where

(*a*) 40 and 41 Vict. C. 68, 7 Edw. 7. C. 4 and 17 and 18 Geo. 5. C. 32
(*b*) S. R. and O. 1939 (No. 532) I. P. 635

the raw vegetables were grown ; and in the case of a consignment landed between the first day of June and the thirtieth day of September in any year each consignment is accompanied by a certificate of a duly authorised Official of the Belgian, German, Luxemburg or Dutch Phytopathological Service (as the case may be) in the Form A or the Form B set out in the Third Schedule to this Order.'

Commencement

4. This Order shall come into operation on the twenty-first day of April, nineteen hundred and forty.

Short Title and Construction

5. This Order may be cited as the Importation of Plants (Amendment) Order of 1940 and shall be read as one with the principal Order, and the principal Order and this Order may be cited together as the Importation of Plants Orders of 1939 and 1940.

REVIEW

Vegetative Propagation of Tropical and Sub-tropical Plantation Crops. By G. St. Clair Feilden and R. J. Garner. *Technical Communication 13 of the Imperial Bureau of Horticulture and Plantation Crops, East Malling, Kent, England*, 1940, pp. 99, bibl. 284, 3*s*. 6*d*.

WHEN in 1936 the Imperial Bureau of Fruit Production issued a technical communication dealing with the vegetative propagation of some 100 fruit varieties grown in the tropics and sub-tropics, it was not without misgivings as to the number of persons likely to be interested. That such fears were unwarranted was quickly shown by the demand on issue. This was immediate and so considerable as to necessitate the reproduction of the publication in the following year.

The present work by the renamed Bureau, which deals, appropriately enough, with the vegetative propagation of some 55 plantation crops, should form a useful companion volume. The help of technical experts has been invoked for adequate treatment of such major crops as rubber, coffee, cacao, etc., while the foreign literature has been thoroughly combed for details of propagation of the less familiar, but nevertheless, important crops.

One feature of the previous work which commended it also to workers in temperate regions is retained and considerably enlarged. That is the section devoted to methods used in vegetative propagation. The descriptions there are supported by simple, clear line drawings of some 17 types of graft and 7 types of budding commonly used in vegetative propagation.

In addition, tropical workers will be glad of the account and illustrated detail of the construction of loosely-woven potting baskets which have been found so useful a substitute for pots in nursery work in the tropics.

For those who wish to study originals a list of references immediately follows the discussion on the propagation of each particular crop.

GIPD—93 ICofAR—4-9-40—750.

THE INDIAN JOURNAL OF AGRICULTURAL SCIENCE

A bi-monthly Scientific Journal of Agriculture and the Allied Sciences, mainly devoted to the publication of the results of original research and field experiments

The Editorial Committee, in the work of examining papers submitted for publication, is assisted in an honorary capacity by a large number of scientists working in various parts of India.

1. Contributions and books and periodicals for review should be addressed to the Imperial Council of Agricultural Research, Publication Section, New Delhi.

2. All communications regarding subscription and advertisements should be addressed to the Manager of Publications, Civil Lines, Delhi.

CONTENTS

VOL. X, PART IV

(August 1940)

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Original articles—